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AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

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PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-FIRST YEAR, 1892–93.

THURSDAY, November 10, 1892.

THE 436th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., President Walker in the chair.

The records of the previous meeting were read and approved. The President then introduced Lieut. H. L. Hawthorne, Fourth United States Artillery, who read a paper on the "New Tactics." The paper is published in full in the present number of the *Quarterly*. After the reading of the paper the President extended the thanks of the Society to Lieutenant Hawthorne, and declared the meeting adjourned.

TUESDAY, November 22, 1892.

The 437th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., President Walker in the chair.

The records of the previous meeting were read and approved. The President then introduced Prof. T. C. Mendenhall, Superintendent of the United States Coast Survey, who read a paper on the "Standards of Length and Weight of the United States." After some discussion the President extended the thanks of the Society to Professor Mendenhall for his very interesting paper, and declared the meeting adjourned.

THURSDAY, December 8, 1892.

The 438th meeting of the SOCIETY OF ARTS was held at the Institute, in the Walker Building, this day at 8 P.M., Mr. George W. Blodgett in the chair.

The records of the previous meeting were read and approved. Dr. Henry P. Talbot, of Boston, and Mr. J. W. Smith, of the Institute, were duly elected Associate Members of the Society. The Society voted to adopt the recommendation of the Executive Committee to assume the assets, including plates and back numbers, and the liabilities of the past year (Vol. IV) of the *Quarterly*.

The following paper was read by title: "Upon the Difficulty with which Water Parts with its Dissolved Oxygen," by Augustus H. Gill, Ph.D.

The Chairman then introduced Mr. I. H. Farnham, of Boston, who read a paper on "Lightning and Strong Current Arresters for Telephones." It is published in full in the present number of the *Quarterly*. The paper was illustrated by diagrams, and at its close Mr. Farnham showed experimentally the efficiency of the different devices. The meeting then adjourned.

THURSDAY, December 22, 1892.

The 439th meeting of the SOCIETY OF ARTS was held at the Institute, in the Walker Building, this day at 8 P.M., Mr. H. M. Howe in the chair.

The records of the previous meeting were read and approved. Dr. A. H. Gill, of the Institute, was duly elected an Associate Member of the Society. The following papers were read by title:

"Tests on the Triple Engine at the Massachusetts Institute of Technology," by C. H. Peabody and E. F. Miller.

"English Composition in Colleges," by George R. Carpenter, Associate Professor of English.

The Chairman then introduced Mr. George D. Burton, President of the Electrical Forging Co., who read a paper on the "Heating and Working of Metals by Electricity." The paper was illustrated with the lantern. It is published in full in the present number of the *Quarterly*. After a short discussion the thanks of the Society were extended to Mr. Burton, and the meeting was adjourned.

CLEMENT W. ANDREWS, *Secretary.*

THE CHANGES OF THE YEAR.

By FRANCIS A. WALKER, LL.D., President of the Institute.

The changes of the year at the Institute have been numerous and important. Unfortunately they have been in the way of loss as well as of gain, two highly valued members of the faculty having gone from us — one by death and one by resignation.

Let us consider first the material changes of the year. The department of Architecture, having outgrown its rooms in the Walker building, has been provided with a building of its own. It may be interesting to pause a moment to refer to the successive homes which this department has occupied during the past eleven years. When I came to the presidency of the Institute, in 1881, the "architects" occupied one half of the room now devoted to free-hand drawing, in the lantern story of the Rogers building. When the Walker building was erected, in 1883, one half of the second story was assigned to this department. When, in 1889, the civil engineers removed to the new Engineering building the Architectural department expanded to fill the whole of the second story, except Professor Cross' lecture room. They have now, as stated, a building all of their own. The front of this building is a continuation of the front of the Engineering building, extending 68 feet southward along Trinity Place towards the Providence railroad. The building contains five stories and a basement. Three of the stories form single, large drawing-rooms, 58 feet in depth, the uppermost being devoted to free-hand drawing, water color, and life-class work. This room is lighted to the point of perfection, having extensive skylights which allow almost every chair that can be placed in the room to be occupied for artistic work to the highest possible advantage. The third story is parted into a drawing-room (for the Fourth Year class) and a library, sumptuously furnished, which not only provides shelves and cases for the one thousand books and the ten thousand photographs belonging to the department, but also a wide spread of tables on which these can be laid out and studied with the

maximum of convenience. The first floor is divided into three lecture and recitation rooms, the largest being equipped with the lime-light. The basement is equally divided into a museum of building appliances and a rough laboratory for clay modeling, for mixing mortars and cements, and for other experimental work. The inner walls of the Architectural building are hung with thesis and other drawings of former students. Here, too, are found the superb architectural drawings of Emanuel Brune and the rich and beautiful *envois* of the Rotch traveling scholars. To say that the architects are happy in their new home would be, as the boys say, "no word for it." The work of the year has been carried on with a zest and delight which clearly indicate how much the Institute might gain could all its departments and services be amply and conveniently provided for.

The removal of the Architectural department has allowed great changes in the Walker building to be effected, to the marked relief of the departments of chemistry, physics, and modern languages. To the last has been assigned an excellent suite of recitation rooms in the second story, with a common room, adjacent, for the use of the five instructors. The Chemical department has been given three additional laboratories on the third floor, two of these being 44 by 30 feet in area. This additional space has allowed a very considerable rearrangement of the chemical work of the Institute, as well as a large extension in the direction of research and thesis work. The Kidder Chemical Laboratories now comprise eighteen laboratories, four lecture rooms, a reading room and library, and a balance room, with offices and supply rooms, making in all thirty rooms, affording ample accommodation for six hundred and twenty-five students in chemistry. But it is, perhaps, the Physical department which has profited most largely by the change. The additional space assigned to Professor Cross has enabled him to extend his two main laboratories each 25 feet toward the north; to fit up a new apparatus room and a large and commodious reading room and library for his department; and to organize in the second story a suite of three laboratories for special research — one in acoustics, one in optics, and one in electricity. Numerous other minor changes in the several buildings of the Institute were made with reference to the work of the current year, with which I will not weary the reader.

The most important of the additions to the apparatus and the machinery of the Institute has been the 300,000 lbs. Emery Testing

Machine, recently set up in the basement of the Engineering building. This great engine was expected to be in place last February; but the delays incident to its size and to the fact of its being the first constructed by Messrs. Sellers & Co., of Philadelphia, prevented it from being available before the opening of the second half of the current year. The new testing machine has already proved itself a most valuable addition to the resources of the school, having a delicacy fully corresponding to its great power. A new Universal Milling Machine has been added to the equipment of the shops, which still remain, as they have long been, the largest and best furnished laboratories for instruction in the mechanic arts to be found in the world. Extensive additions have also been made, from the designs of Professor Porter, to our unequaled laboratory of Hydraulic Engineering, enabling that department to carry on to the best effect every species of hydraulic experiment which can be conducted within walls. Extensive additions have also been made during the year to all the scientific and technical libraries. No fewer than 362 periodicals, including all scientific and technical journals and magazines which any department deems it important or even desirable to have, are now regularly taken at the Institute. The approaching completion of the new Boston Public Library in our immediate neighborhood will further add greatly to the resources of the school.

But the greatest of the changes in the material conditions of the Institute of Technology which have taken place during the last twelve months has been through the acquisition of land. As I write, the Institute has just acquired the skating-rink property on Clarendon Street, and the Jordan land lying between the Institute property on Trinity Place and the Providence railroad. These two estates aggregate about 50,000 square feet; the sum paid for them was in the neighborhood of $275,000. So great is the poverty of the Institute that it has been necessary to raise nearly the entire amount by mortgage of the properties so purchased and of the Architectural and Engineering buildings. To the old-fashioned college trustee such a transaction would seem little short of madness; but the greatness of the Institute of Technology is mainly due to the fact that from the first its destinies have been controlled by large-minded business men who dared to take risks, to bank upon the future, and to trust to the munificence of the citizens of Boston and Massachusetts. Ten years ago we ran in debt $300,000 for the erection of the Walker building

and the Workshops and for the purchase of the land on Garrison Street. To-day that debt is paid; the Institute is three times as large as it then was; its work is better done in every department; and its reputation and influence have been greatly extended. In purchasing the new land the trustees of 1893 have recognized the fact that a new era in the life of the school has opened, and that the new exigencies and necessities must be met with the same courage and comprehension which characterized the action of their predecessors, or else the Institute must fall short of its high mission and fail of some part of the duty which the country demands of it.

Let us turn now to the changes in the *personnel* of the Institute of Technology the past year. In Mr. James B. Francis, of Lowell, the Corporation has lost one of its charter members, one of its firmest and most devoted friends, the greatest of American hydraulic engineers, and one of the foremost engineers of the age. In another article of this volume of the *Quarterly* will be found the just, feeling, and discriminating eulogy upon Mr. Francis read at the last meeting of the Corporation by his worthy colleague and lifelong friend, Mr. Hiram F. Mills. In Mr. M. Denman Ross the Corporation has lost another of its charter members, one of the projectors of the Back Bay district of Boston, and an early and persistent advocate of the scheme of founding in that district a great school of arts and sciences.

The faculty, likewise, has lost two of its members during the year. Professor Luquiens has resigned the professorship of modern languages to accept the professorship of the Romance languages at Yale — a position in which his superb scholarship will find ampler opportunities than were afforded it by the elementary instruction which he had for eighteen years conducted at the Institute of Technology with such marked success. Professor Luquiens carries to his new post of duty the cordial affection and respect of a host of "Institute men."

On the 28th of November, 1892, Professor Eugène Létang, for twenty-one years in charge of Architectural Design at the Institute, died after a brief illness, to the great loss of the school and to the inexpressible regret of all his former associates and pupils. During the long term of his service here, Professor Létang has never ceased to exert a profound influence upon the study and practice of architecture in the United States, and of few men can it be so truly said that his influence will survive him. Hundreds of his pupils are now leading architectural practice in all parts of the United States under the

inspiration they derived from him during their school life here, and the impulse which he has given to sincere, pure, and high-minded architecture in this new country will be accelerated rather than retarded with the passage of years.

The problem of filling Professor Létang's place was necessarily one of very great difficulty. His work for the present year has been taken in charge by Mr. Samuel W. Mead, of the firm of Cabot, Everett & Mead. Mr. Mead, one of the earliest recipients of the Rotch traveling scholarship and an artist who is in complete sympathy with the thoughtful, thorough, and academic spirit which characterized the drawing-room work under Professor Létang, has applied himself with the highest zeal and intelligence to prevent any falling off in the Design of the year, while Professor Chandler and his assistants have thrown themselves into the breach to repair as far as possible the loss which has been sustained. Meanwhile the corporation have felt that it was their duty to go back again to that highest source of modern inspiration in art from which Professor Létang came directly to us. In searching throughout France among the recent graduates of the École des Beaux Arts for that one who should be most worthy to succeed our departed associate, we have received valuable advice and assistance from Mr. Arthur W. Wheelwright and Mr. J. Randolph Coolidge, Jr. It is with great gratification that I now announce, through the pages of the *Technology Quarterly*, a result more fortunate than we had presumed to expect. Monsieur D. Despradelle, one of the most distinguished of recent graduates of the Beaux Arts, and an architect already of assured position in his own country, has accepted the associate professorship of architectural design. M. Despradelle graduated with much distinction at the unusually early age of twenty-five. He had taken most of the minor prizes of his time, and in the competition for the Prix de Rome won the rank of Premier Second. M. Despradelle is now *Sous Inspecteur aux travaux des Bâtiments civils des Monuments de l'État.*

Still another death has occurred among the corps of instructors since I last wrote for the *Quarterly* on the "Changes of the Year." In August last Mr. George V. McLauthlin, instructor in biology, was drowned off the shore while bathing at Nahant. Mr. McLauthlin graduated in chemistry with the class of 1888. Before his untimely death he had already attained a high position both as teacher and as investigator, and bade fair to become one of the most distinguished

graduates of the Institute. Other losses to the corps of instructors have been through the resignation of Dr. Gardiner and Messrs. Williston, Cobb, Heller, and E. V. French. The corps of instructors has been reënforced the present year by the appointment of Messrs. Ch. L. N. Bernard, Joseph Blachstein, and Johann Meyer, in modern languages; Messrs. Harry M. Goodwin and Wm. L. Smith, in physics; Mr. Richard E. Edes, in biology; Mr. Edward Robinson, in mechanical drawing; Messrs. Leonard M. Passano and Wm. H. Metzler, in mathematics.

The changes in the faculty other than those mentioned have been through the promotion of Associate Professors Dewey and Levermore to be Professors of Economics and Statistics and of History, respectively, and of Assistant Professor H. W. Tyler to be Associate Professor of Mathematics; through the appointment of instructors Henry P. Talbot, Dana P. Bartlett, Edward F. Miller, and Frank Vogel to be Assistant Professors of Analytic Chemistry, Mathematics, Steam Engineering, and Modern Languages, respectively; and, lastly, through the appointment, for the first time in fourteen years, of a military instructor with faculty rank. The last mentioned appointment is one of so much consequence to the school that I will speak of it more at length. Ever since the foundation of the Institute instruction in military tactics has been given in the school, as provided by the act of Congress of July 2, 1862, under which we receive a portion of our annual income. The requirement of military instruction has always been honestly dealt with here — a substantial course being given, without interruption, to the students of the first year. During the summer of 1891 the Executive Committee of the Corporation determined that it was best, in view of the large number of students in the first year, that the instruction in military tactics should hereafter be given by an officer of the United States Army, as contemplated, although not required, by the act of 1862. They accordingly addressed the Honorable Secretary of War with the request for the detail of an officer for this service. In compliance with that application Lieut. Harry L. Hawthorne, of the Fourth Artillery, was assigned to service at the Institute, relieving in this duty Gen. Hobart Moore, who had for many years given the instruction in this department with the greatest care, pains, and effort, and with all the success it was reasonable to expect under civilian management.

Lieutenant Hawthorne entered the Naval Academy at Annapolis

in 1878, graduating in 1882. He was on sea service until June 1, 1884, when he passed his final examinations for appointment as an officer of the navy. The navy at that time affording opportunity for commissioning but a small part of the graduates of the academy, he was honorably discharged from the service under the act of Congress approved August 5, 1882. Passing examinations at once for the military service, he was commissioned second lieutenant of the Second Artillery in October, 1884. He took part in the operations against the Sioux Indians in the winter of 1890–91, and commanded the artillery in the fight at Wounded Knee Creek, December 9, 1890, where he was severely wounded. For gallantry and ability displayed on this occasion he was recommended for brevets of first lieutenant and captain, was mentioned in General Orders from the Headquarters of the Army, and was presented with a medal by Congress. He received his commission as first lieutenant August 28, 1891. Lieutenant Hawthorne entered upon his duties, with the rank of professor in the faculty, about the middle of March, and took up the problem of instruction in military tactics in a school of this character — for the problem must necessarily vary greatly with the varying character of schools — with much intelligence, spirit, and activity.

The substitution of an instructor in military tactics from the regular army, in place of an instructor from civil life, is of special importance at the present time by reason of the revolutionary changes recently introduced into the United States army tactics. So extensive are those changes, both in the form and in the spirit of the evolutions presented, that it must be a work of the greatest difficulty for any one not a professional soldier to completely master the new tactics. It is even a question whether it would not be more difficult for one who had been brought up under the old system, and become imbued with its spirit and familiar with its methods, to possess himself of the new tactics, than for one who had had no experience whatever in military matters. So diverse are the modern evolutions from those which they supersede, so hostile their spirit, that it is fairly a question whether any considerable part of the militia of the United States have yet come, or will for years come, to practice them according to their true military conception. Strongly contrasted as are formations under the two systems, that difference is yet not so great as is the difference in the relations between officers and men, and between the line and the staff. Lieutenant Hawthorne is by exceptional experiences peculiarly qualified to

take up this task of teaching the new tactics, in their methods and in their spirit.

The students of the Institute number 1,060 the current year, as against 1,011 in 1891–92. The last graduating class numbered 132, and with these went thirty or forty young men who had for four years enjoyed all the advantages of instruction at the Institute, but who had not attained its degree. A considerable number of students have also, as is usual, left the present second, third, and fourth year classes — some on account of deficiency of financial means; others from failure in scholarship; others from the exhaustion of the scholarly impulse; and others, still, with a view to accepting positions of a professional character. Except for the inevitable large annual loss from the first year class, due to the fact that many come to us each year who have no fitness for our work, or no disposition to serious study — the last indicated is the chief of the causes of the loss of students between one year and another at the Institute of Technology. Every year a considerable number of students leave at the end of their second or their third year to take professional positions. Some do this out of an impatience to get to work; others because they are unwilling to call upon their friends for further sacrifices on their account. Many of these, it is to be said, achieve no small degree of success, having learned while at the Institute to work hard when they work and to concentrate their powers upon the immediate object of study, and having acquired, also, no inconsiderable professional accomplishments.

The incoming first-year class numbers, of regular students 314, and of special students 48, making a total of 362. In addition to these, 80 have entered as regular or special students in the upper classes, making the total number of new men, 442. Our students come from thirty-nine States of the Union, besides the District of Columbia, Utah, and New Mexico; sixteen foreign countries are also represented on our lists, including England, Scotland, Ireland, France, Belgium, and Holland. Of the native students, 603 are from Massachusetts. Of these, Suffolk and Middlesex Counties send 185 each; Essex, 75; Norfolk, 72. One hundred and eleven Massachusetts towns send students to the Institute. The average age on entrance is eighteen years and ten months. Forty-nine graduates from institutions conferring degrees are included in our lists. Of these, six are our own graduates; twelve are from Harvard University; while twenty-five other colleges and universities are represented by one or more graduates. Forty-one women are students at the Institute.

The changes of the year affecting the several courses of study have, of course, been numerous, but few of them are of sufficient consequence to require description in this brief sketch. The most important of all is that by which the choice of courses has been made to take place at the opening of the second term instead of at the opening of the second year, as heretofore. This is a change which the faculty has long desired to bring about, but which has heretofore been withstood by one consideration or another. The advantages anticipated under the new rule are as follows:

(1) The students will come earlier under department supervision. Each student will, from the close of the first term, belong to a department, to the head of which he may resort for advice or needed assistance. The heads of departments, on the other hand, will begin looking after their own men one term earlier.

(2) The interest of the student in the school and in his own work will be increased as he feels himself a member of a distinct course, and sees himself ranked as such, instead of being merely one individual in a great unclassified body of students.

(3) The long novitiate of the first year will now be abridged one half, and the students will earlier get a taste of professional study, although the main part of their work will necessarily still be of a preparatory character.

(4) There will be a better adaptation of the studies of the second term to the subsequent work of each student. For example, heretofore it has been necessary to extend one and the same chemical course throughout the first year. Those who were in the result to go into an engineering course, or into architecture, have been obliged to take a somewhat longer and a somewhat different course than would have been given them in the interest of general training, or with reference to their subsequent studies. Men, on the other hand, who were in the result to enter some chemical course, such as chemistry, metallurgy, biology or geology, have been given a somewhat shorter and a somewhat different course than might have been thought desirable. In other words, the chemical work of the second half of the first year has thus far been in the nature of a compromise, precisely meeting the needs of neither the "chemical courses" on the one hand, nor the "mathematical courses" on the other. Under the new arrangement the chemical work of this term will be adapted to the requirements of each group of students. The architectural students will drop

chemistry entirely at the close of the first half-year, putting the time thus saved to use in drawing. The students of the course in "General Studies" will take physical laboratory work the second half-year in place of chemistry, securing thus, it is believed, a more varied training in experimentation and observation. The change fixing the choice of courses at the middle of the first year has also enabled the faculty to improve the instruction in first year drawing and descriptive geometry in several particulars.

The only other change in the courses of instruction to which I will refer is the very marked development of the option in naval architecture. This is a matter of such prime importance that I should feel called upon to speak of it at length were it not that the next number of the *Quarterly* will contain a full description of the course by Professor Peabody, to whom the development of this branch of instruction has mainly been due.

It remains only to say a word regarding the finances of the Institute. The Institute was poor last year, and the Institute is poor this year. Whether the Institute was poorer last year than this year, or is poorer this year than last year, its situation and needs being taken into account, are questions which it would require more mathematics than I have at command to answer satisfactorily. In any case the Institute is very, very poor. Magnificent possibilities of good work for the cause of education and for the development of the industries of Massachusetts, New England, and the United States, lie all around us. The only limit to our usefulness is found in our scanty means. For all which the munificence of the government or of private individuals shall place in its hands the Institute is prepared to return, "some thirty, some sixty, and some an hundred fold," to the State and to the community.

EUGÈNE LÉTANG.

By ARTHUR ROTCH.

Written for the Committee on the Department of Architecture.

The history of the Institute is almost an unbroken record of the appearance of men upon the scene at the most opportune moment. One of the most remarkable examples of this was the advent of Prof. Eugène Létang to its corps of professors at a time when there was in America no other opportunity for an academic education in architecture. Shortly before, in this, the country most needing trained architects, the Institute had opened its Department of Architecture and offered to those about to build up a new world an opportunity to know something beyond the rule-of-thumb office training of their predecessors.

Professor Ware, the first head of this department, after three experimental years turned to the École des Beaux Arts of Paris for help, and through his friends obtained the assistance of one of its most promising pupils. A strange and powerful personality was that of the foreign instructor, whose indifference to anything but his own personal work among his students estranged him at first from a general interest in courses of the Institute. He had no thought for ingratiating himself with his fellow professors, no time for theoretical plans for reorganizing his department or for extending it; for every day were not some of his pupils bent on drawing out some abominably irrational design? And was he not responsible for every bad example coming from the Institute? And so he fell with almost savage intensity upon the work of the students, and with few words of broken English, but endless graphic illustrations, forced upon each an inkling of the principles of rational constructive architecture. The task was almost superhuman. The traditions of the country at large and those of most of the profession were against him. A theoretical study of architecture was supposed by those who escaped from the drudgery of an office to mean a cultivation of the æsthetic imagination and a

discovery in the clouds of some original and beautiful American style. He sternly faced such enthusiasts with Socratic questions of why or what — "What is the purpose of your building, and how can you with your materials accomplish it and express it?" No eloquent aspiration, no longing for mere novelty, could turn aside his pitiless logic; and from the moment of his coming, when the Victorian Gothic was rampant, on through the years of Romanesque and Queen Anne fads, he brusquely forced his pupils along the lines of a logical structural style of design. Many were the revolts among the cleverer pupils, who were anxious to follow the style of the day; but few went forth from his teaching without a conscientious consideration of the beauty of truth and logic in design.

It is not too much to say that the result of Eugène Létang's intense scorn of sham and unconstructive designs, and of his admiration for a rational classic architecture, has been the means (through the graduates of the Institute) of changing the whole sentiment of the country, and has led to the erection in this style, with which he has identified himself and the Institute, of the magnificent group of classic buildings for the Columbian Exhibition at Chicago. These, designed by architects from all sections of the country, cannot fail to exert great and permanent influence for good on the future of architecture in America. But such fiery intensity working through personal and individual contact with the students could not fail to exhaust the nervous system of even Professor Létang's rugged constitution. His instruction was not through lectures, but was a personal wrestling, so to speak, with each student; and the result was an enormous outgo of nervous energy, followed by the inevitable reaction.

After the first half a dozen years he annually declared he could not serve another year, but as regularly returned to his post. He refused all professional opportunities of what promised wider fame and larger fortune. His whole life was bound up in his pupils; each was a drowning man whom he alone could save; and so year after year he worked on with diminished strength, but never lagging energy, till, after fourteen years, even his energy gave out, and then a vacation of one year was granted him. It was a crucial test. Could an influence so purely personal be removed without making a serious break in the department's work, and how far would the removal of his constant personal supervision lower the standard of that year's work? The question involved the ultimate value of his influence at the Institute. But his

old and devoted pupils rallied to the department, and at the end of the year the result showed no falling off from the preceding standard. This was a triumph most gratifying to all. It showed that his intense personality had formed traditions which were henceforth to become the heritage of the Institute, and which no longer partook of an uncertain personal character. It also proved that his vivid enthusiasm had brought about in a few years convictions and traditions which usually are the result of many years and many persons following a prescribed method.

After his vacation, Professor Létang returned to his work with new interest, and for the last five years the results have shown annually a higher standard and a wider scope. Throughout the length and breadth of the country his death was a personal shock to architects, and the most appreciative notices and tributes to the great work which he so modestly wrought have been published. With all the fine Gallic artistic sense which we might expect from a graduate of the École des Beaux Arts, he combined to an extraordinary degree a rugged sincerity whose effect upon others it would be impossible to overestimate. Esteem and a manly affection for him is the universal tribute which arises spontaneously from the hundreds of students who have passed forth from his instruction and are now the leading authorities in their profession.

The Institute most fully honors itself in honoring the memory of one who has contributed so much to the advancement of our national architecture.

Boston, December 14, 1892.

THE NEW TACTICS.

By Lieut. H. L. HAWTHORNE, Fourth U. S. Artillery.

Read November 10, 1892.

The changes that have been made in tactics have been made by leaps, either under the magic touch of a master soldier or by the more potent development of military necessity. The principal military influence has been the elaboration of the killing weapon; but owing to the sluggishness of the inventive faculty, or at least of that part which was devoted to the improvement of military arms subsequent to the times of Frederick the Great and the first Napoleon, the changes brought about by these men were allowed to remain undisturbed for many years.

The American Civil War marks the beginning of a very rapid growth in the improvement of tactics, brought about principally by the adoption and use of the breech-loading arm. Although this weapon was used to but a limited extent, still the lessons it taught were sufficiently distinct to cause the introduction of the single rank formation as being especially adapted to its use. The Austro-Prussian, the Franco-German, and the Russo-Turkish wars were replete with hints to the military leaders, and showed them plainly that the rapid loading arms not only seriously affected the old conditions, but gave rise to new ones on the field of battle, which necessitated changes in the methods of handling troops while subject to their fire. Since the Franco-German war all the leading nations of Europe have modified or changed their tactics once or oftener. The Germans have modified theirs five times, Italy and Russia each three times, and France and Austria each twice. The limits of this paper prevent me from describing more than a single phase of the subject of tactics. I shall select, therefore, that part relating to the maneuvering of troops on the field of battle in formations for attack, and attempt to show to what we have been led by the latest developments in this direction.

During our war, a brigade was composed of from three to eight regiments, and was usually formed for combat in two lines; the first line, covered by skirmishers, generally consisted of two or more regiments in line of battle; the second line was frequently similarly formed, but sometimes it was in close column of regiments or battalions, and at times in double column.

The arms then used could not prevent the skirmishers advancing within two hundred yards or less of a position with impunity, and there they awaited the coming of the assaulting lines, which kept an almost parade formation, sometimes not firing a shot until ready to attack with the bayonet. On the other hand, the defense waited the attack behind its breastworks, having the ground in front carefully prepared to delay or confuse the assaulting lines, where they would be held under deliberate fire as long as possible. In densely wooded districts, both sides would have their skirmishers in front, the defense giving ground until the opposing lines came so close — at times within twenty or thirty yards of each other — that the fire was as murderous and demoralizing as in any of the engagements in later wars, where both combatants used breech-loading arms. When muzzle-loading arms were used, there were always intervals with the companies when the firing almost ceased, as when the majority of the men were loading. During these intervals the captains had no difficulty in making themselves heard; a single company in close order covered a very small front, the men being shoulder to shoulder, and its commander could maneuver it with little difficulty; at critical moments, or where necessary, he could withhold the fire entirely or until it would be most effective; reinforcements took their places as units on the right or left of his command, and if necessary he could close his men to the right or left to make room for them; his control, comparatively, was complete. Now, however, with breech-loading arms it is the reverse; the fire once started is unceasing; the captain can rarely make his commands heard; he finds it difficult, if not impossible, to control the firing; his company is spread over a much more extensive front; he has to advance it over very much longer distances under a more severe fire, alternately deploying to decrease its losses when without cover, or rallying behind shelter to fire or resist the enemy's attacks; his men, scattered in hollows or ditches for protection, are loth to renew the advance, and finally when reinforcements come to his assistance he cannot close his men into the right or left to make room for

them; he finds himself surrounded by strange faces, his company disintegrated, and himself powerless. If this condition of affairs exists in the immediate presence of the captains, how much more powerless are those whose greater rank compels them to be farther to the rear and who are therefore less able to influence the results!

This utter want of cohesion in bodies of troops when brought under the fire of the modern rifle in the old formations was noticed early in the Franco-German war, and steps were taken by the German leaders, even in the progress of the campaigns, to make changes by which their losses were diminished. Since that time, and from the study of the Russo-Turkish war, military thinkers have about solved the best tactical methods of overcoming the difficulties enumerated above. These difficulties are illustrated in the accounts of the battles of the Franco-German and Russo-Turkish wars, where the marked features due to the use of rapid firing arms were: the disadvantages under which the superior officers labored in retaining control and direction of their troops while advancing to the attack; and the entire loss of control, sometimes even by the company officers, after the men were once engaged. This was due to the large size of the tactical units employed, their compelled deployment by the severity of the opponent's fire at distances varying from 2,000 to 3,000 yards from the enemy, and the dispersion of their component parts during the subsequent advance over these long distances. In the attack on the Rotherburg, for instance, "there were thirty-two companies of two different armies mixed up in utter confusion without unity of command." The difficulty of command is increased by the mixture of the different organizations, as we read that at Sedan "other Infantry detachments of the Eleventh Army Corps and of the Forty-sixth Regiment and Fifth Rifle Battalion had become mixed up with the Forty-third Brigade, and in the course of the engagement the regiments of the latter were likewise so intermingled that the officer in command of the brigade had at his disposal a mere multitude of men about one battalion (1,000) strong, composed of the most varied troops." The problem, then, for the attack of infantry would seem to be, how best to form and direct troops that they may be brought up to a defensive position without losing proper order and control, and to obtain adequate results for the men and material employed and at a minimum loss. The second consideration should be, how best to govern the fire

of the attack; but as this question would lead into the still unsolved problem of "fire tactics," it must be set aside for the present.

As we have seen, the control, under fire, by a single voice of so large a body of men as a company was found impracticable, and from this consideration there naturally followed the subdivision of the company; first into platoons, then sections, and finally squads, each under its own chief, yet held together by a common authority whose essential duty it was to direct and command. This alone would not insure proper control of the company, but by decreasing the amount of its front when deployed, by increasing its depth, the company commander could, from a central position, give direction to the attack, keep in touch with the *morale* of his fighting line, and give strength and confidence to his men by timely reinforcements. The attack in extended order does not, however, mean that a body shall suffer entire disintegration, but that its close order formations and rigid discipline should be maintained after the smaller groups have been formed.

The tendency towards dispersion could easily degenerate into a laxity fatal to the influence of superior officers, but it is at this point that careful military training asserts its power, and men are held and moved through an automism produced by a thorough peace preparation. Discipline must not be lessened by too much individualism. This seems to be the tendency of the German tactics. I am of the opinion, however, that the tactics we have now adopted stop short of total surrender to subordinates. It is believed that the more a man is taught to think and act for himself the less he is apt to be governed by the thoughts and actions of others. Our book, therefore, lays much stress on the careful training of masses. It furnishes us with a full list of maneuvers capable of filling all the requirements of actual campaigning, and enables the peace practice to develop a precision and order which any amount of extension of subdivisions cannot influence harmfully.

To show what changes have been introduced by the new regulations a brief comparison of the methods laid down by General Upton with those of the present book is necessary. Under the old system the battalion was the tactical unit, but could be divided into from two to ten companies. In preparing for attack a reserve was formed of two or three companies, and the size of company reserves designated by the colonel. The deployment as skirmishers was then made on a four of a particular company. In this way several hundred men

were spread out in a thin and more or less uncontrolled line over a large front, but held in hand directly by the bugle or the commands of one man. When this cloud of individuals entered the enemy's fire, all attempts at control beyond the signal for withdrawal ceased. The men acted entirely on their own responsibility, keeping up their fire, and, in spite of the slow loading process, usually expended their ammunition before the critical moment of the attack had arrived. No rules were laid down for the gradual strengthening of this line by judicious use of supports or of increasing the intensity of the fire. When it became necessary to reinforce, the entire reserve, including company reserves, were brought up at the same time, and being deployed as skirmishers a general mingling of companies took place. This, however, was not so vital considering that the colonel controlled, or tried to control, the detailed action of the entire battalion.

A later and, if possible, a worse method of deployment was introduced, by which the battalion was deployed by the numbers. There was thus created one, two, three, or four lines of skirmishers with half or more of the battalion as a reserve. The natural consequence of this method would be that these successive thin lines in the long advance under fire would lose their cohesion, either because of the difficulties presented by the ground or because the men composing them would naturally avoid the more exposed places and collect together behind cover. In availing themselves of this they would become crowded, and a large proportion of their fire be masked; the officers, owing to the mixture of strange men with their commands, would lose control, and advantage would be taken of this by the stragglers, when the line again moved forward, to remain behind and go to the rear. The second line would encounter similar troubles; and owing to the strong desire of the men to fire would soon be merged with the first, so that its value as a support would be of no practical benefit. This method of deployment had an advantage over the other, as the front covered was within the control of one man; whereas in the first case the front covered was so great that the line could not possibly be controlled when subjected to the fire of modern arms in the long advance.

It is perhaps fair to say that the authors of the old drill methods could not be expected to foresee the wonderful changes that have taken place since the introduction of the present infantry arm. In the days of Upton skirmishers were used to "annoy the enemy and exhaust his fire before the main attack, or to pursue him promptly

after a repulse." This last employment condemns itself when we consider that after a long and hotly contested advance the exhausted and excited skirmishers could scarcely be relied upon to conduct an orderly and rapid pursuit. In this sense, then, the advance of skirmishers was not in truth an attack. This was made, as before remarked, in what was commonly termed lines of battle; or, in other words, one or more solid lines of double rank moving at the charge.

It is plain that the conditions of the modern battlefield will permit of no such extension of lines, nor of the mixing of commands, nor of uncontrolled fire, nor of tardy and uncertain support. The new tactics must enable us to have closed formations in such small units that they can move with the greatest rapidity, give the maximum fire, and yet be under complete control; therefore there must be a greater subdivision of our tactical units to get the advantages of this dispersed order, and while their commanders are given more independence we must be careful, above all things, to leave the direction of the combat where it rightfully belongs — in the hands of the superior officers.

How does the new drill seek to accomplish this? The Board has wisely retained the regimental administrative unit. This is divided into three battalions of four companies each. The battalions have their own commanders, who are responsible for their instruction. No handier unit than the four-company battalion can be obtained for use on any battlefield. It gives a compact body of effectives numbering from 350 to 400 men more than the German or French company column, but more manageable and inherently possessed of greater power of discipline because of its permanent division into four companies, each with its commander. The captains must render direct and positive assistance to the field officers, and to make this more effective they have more independence than heretofore in carrying out their instructions. The captain in turn must have the assistance of his subordinates, who, to be responsible, must have direct command; therefore the subdivision into platoons is made and becomes a unit of importance for control and movement in the advance to the attack or on the fighting line. But even this body is too large to be controlled without assistance where it is so necessary to prevent a waste of ammunition; to have movements executed with the greatest rapidity; to utilize shelter and to prevent straggling. Therefore the platoon is subdivided — first into sections, and then into squads. But a front of four men was already the base of our system, so this unit

was utilized by giving it a commander — a non-commissioned officer — thus obtaining not only the equivalent of the foreign "fire unit" or "group," but also the active assistance, on the march and in battle, of our non-commissioned officers, by giving them direct control and responsibility. We thus do away with the system of numbering, which consumed time, determined the unit for the time being only, and necessitated reforming whenever the unit was broken up or became disorganized from any cause.

We have seen the incapabilities of the old organization when confronting the magazine long-range rifle. Now let us examine the methods which our present regulations have made possible, and enquire whether they will answer the requirements of the modern field of battle already specified.

The book begins at the very foundation training found and acknowledged by all the leading armies of Europe to be essential to success under the ordeal of the modern rifle. It says: "The squad is the basis of the extended order." This is now such a well-recognized unit that it needs no defense nor explanation. With this, then, as a basis, it naturally follows that its integrity should be preserved, and men be trained to regard it as the unit from which they ought never to be separated. Every effort is made to bring into prominence the importance of control down to the smallest group, and therefore the non-commissioned officer is raised into command and responsibility as a leader. Squad leading, then, is to be another important direction of development.

The object of this, we read, is "to prepare the squad for the battle exercises, by training the men to coöperate with their leader and conform instantly to his wishes." What a contrast to the old methods of the employment of our junior officers! If not in ranks, where their influence was no greater than any other file, they acted as file-closers, where they had "general charge of the men in their front to rectify mistakes and insure steadiness and promptness in the ranks, prevent men from falling out, etc."

But these directions, excellent in themselves, fixed such an indefinite responsibility that it was hardly practicable to enforce them. The non-commissioned officer, having no direct command, felt no responsibility; he failed to prevent men from falling out, either on the march or in battle, and in the latter case especially the evil increased to enormous proportions. In fact, at such times, the men in line, being

unaccustomed to having the non-commissioned officers in their rear exercise any control over them, paid but little attention to their directions, and not infrequently they were inclined to resent what they regarded as uncalled for interference. Now, on the other hand, just as soon as the sergeant or corporal is placed in the position of a section or squad commander, and is given direct control of a number of men, he finds himself with a distinct charge which excites his feelings of responsibility; he has no hesitation in trying to control his men, and they soon acquire a feeling of subordination and obedience to his commands; the captain and lieutenants thus receive the direct and positive assistance of the best men in the company in assuring the execution of their commands, and a firm basis is established for the preservation of their control in times of the greatest excitement and danger. I have elaborated this idea because I feel that upon this principle the whole fabric of modern tactics is built. Not only is it confirmed by the practice of foreign nations, who lead in military prowess and development, but the stories of modern battles furnish us with ample testimony in its favor.

The new drill lays down a carefully devised progression of training, beginning, as has been shown, with the men in squads and sections under non-commissioned officers; then as squads and sections under platoon leaders, with definite and distinct duties on the field of battle; then the gradual expansion of command, duties, and responsibilities up through the captains, battalion commanders, colonels, brigade commanders to the commander of the division. There is not a break in this succession, and the distinct powers of each are carefully laid down. It is even prescribed that under certain conditions of ground and cover the judgment of officers may be used, but this in turn is limited to certain definite movements or authority.

In contrast to what has been shown as the method of advance over ground under fire by the old tactics, let us picture the movements of an attacking battalion, one of a regiment organized under the present rules and governed by the principles laid down in the Infantry Drill Regulations of the United States Army.

A division of infantry about 10,000 strong awaits the completion of the preparatory stage of the combat to advance against a position on the edge of a wood some 3,500 yards in front. The ground is open, but affords shelter here and there in shallow ravines and gentle undulations. They are such, however, that a column could advance

along them but for short distances, thus compelling early separation into small bodies.

The design of the division commander is to make a powerful attack; he therefore orders the three brigades into the fighting line, instructing his brigade commanders to form their regiments side by side, each regiment in three lines, and gives them their order in line. The brigade commanders then issue the necessary orders for the above formation, designating the formation for the advance, leaving to the colonels of regiments to decide upon the moment for passing from close to extended order. The colonels then designate the battalions to form the fighting line, the support, and reserve; point out the position for the reserve; specify the formation for the fighting line and support; indicate the point at which the first deployment shall take place; and point out the objective and general direction of the advance. When the majors of the battalions chosen for the fighting line receive orders to attack, each designates two companies to form the fighting line and those for the support and reserve, gives instructions for forming line of sections or squads or deploying as skirmishers, and indicates the point of direction and the object of the movement.

The moment for the advance having come, the signal for the forward movement is made, and the entire division breaks cover and advances in the direction of the enemy in line of brigades, each brigade in line of regiments in column of battalions. The actual front of this mass of men is about 1,775 yards. The front occupied by the men themselves is about 1,450 yards. After a short forward movement the battalions of the support and reserve halt, the fighting battalions break into lines of companies in columns of fours and continue the advance. Any cover sufficient to accommodate any of these is taken advantage of, care being taken that the advance is not delayed. The battalions having reached the point indicated for deployment, each major gives the commands for taking the battle formation. The captains of companies for the fighting line designate the sections for supports and cause their companies to advance in the given direction, and at the signal from the major to take the battle formation. To do this each captain in the fighting line orders a few scouts sent forward, designates the non-commissioned officer to command them, indicating the objective to him and to the chiefs of platoons and sections. The captain then designates two sections, preferably the second and third, for the firing line, and when the scouts having gained about 150 yards

to the front gives the necessary commands for the extension. The supports halt while the firing line moves forward, and when at the designated distance from the enemy the lines are deployed into sections and then squads. The orders relative to the opening of fire will more or less modify the above conditions, but only as to the time of deployment and the rapidity of the advance. As I have pointed out, this question of fire tactics is so closely allied to the power of the weapon used that no settled rules concerning the fire have as yet been decided upon. Long distance firing is supported by some writers, and by others condemned. All unite on the employment of volley firing up to the latest possible moment, and that feature is a prominent one in our new regulations. The settlement of the question of the proper employment of fire will also decide the various distances to be taken in the advance by the supporting bodies and the reserves, and the points at which it will be necessary to take the various deployed formations. The drill regulations do specify the distances for the latter cases; but already the book has fallen behind the conditions created by the newest small arms. It seems to me that it would have been wise to have stated in general terms the advantages of certain fire and formations, specifying the value of the influences of ground, different kinds of cover, and character of the attack, rather than to have laid down hard and fast rules which depend on the power of so changeable a thing as a firearm.

When the squads can no longer advance as solid bodies, either by reason of lack of cover or because it is desirable to develop the fire of the attack more quickly, they are deployed as skirmishers, care being taken to avoid the mixing of sections and squads. The line of skirmishers soon overtakes the scouts, who join it. As the fire becomes more severe, advance from cover to cover by rushes is made by the whole line if possible. When the rushes begin it is an indication that the power of the attack is waning, and it is at this stage, therefore, that the moral effect of the supports is made to tell. They join the firing line successively in groups, giving it momentum for the next rush and renewing its courage. The handling of the supports and reserve is where the highest type of fighting ability will show itself. The brigade commander has full control of the regimental reserves, leaving to the colonels the employment of the supporting battalion. The reserve of the battalion receives its orders from its

commander only, who may also hasten or delay the reinforcement by the company supports. This may be left to the judgment of the company commanders, but it is a wise provision that places this also in the hands of the commander whose greater distance from the disturbing influence of the fire and whose wider field of view leave his judgment cooler and broader.

As the opposing fire grows in intensity the unity of the attacking line breaks more and more, throwing on the small group commanders more and more responsibility for the continuance of the advance. The rushes are by small groups, pushed now and then by reinforcing bodies, and covered in the short advances by volleys delivered on either side. The company supports have been absorbed and part of the battalion reserve joins the firing line, while the battalion in the second line advances nearer under cover of the rapid fire which is now opened. If the rapid fire does not shake the enemy, the remainder of the battalion reserve is quickly brought up, and another rush made, followed by a rapid fire. During this fire the battalion of the second line reinforces the firing line; at the signal from the colonel the field music sounds the charge, and the whole line rushes upon the enemy. The third battalion still remains, on which the attacking troops may rally if repulsed, or by which a pursuit may be attempted or a counter attack resisted.

Assuming forty paces for the front of a company, then observing the proper intervals between subdivisions, the front of a regiment in columns of battalions would be 169 paces. The attack of this regiment must cover this front and half the interval between it and the regiments on its flanks, or 48 paces. Three battalions of 380 men each are therefore made to attack a front of 217 paces.

The depth of the attacking column is such that by decreasing in this direction it will make up not only for all losses in the advance, but will gradually increase the intensity of the attacking fire and make the assaulting line so solid that it is no longer a line or swarm of skirmishers, but has all the momentum and confidence of the old shoulder to shoulder line of battle. We thus see that assuming a loss of 40 per cent. for the fighting line and a loss of 20 per cent. for the supporting battalion during the advance, we shall still have for the final charge 912 men to 217 paces or more than a solid line of four ranks.

The new drill teaches much more than this single phase of the business of the soldier, but the excellence of this ought to give us confidence as to the worth of the rest. It is hard to draw the line between drill and tactics. To go into the minutiæ of minor tactics would have required a volume many times larger than the present one. The literature on this subject is already confusing in its richness, and the military student finds the different phases and branches of the military art growing sufficiently broad to make each a distinct specialty.

A final word as to the question of the importance of drill. It is becoming too fashionable to regard drill as the meager mental limits of the half informed subaltern. Those who entertain such an opinion are usually men who have never experienced the actual difficulties that arise in taking the very first step, with poorly drilled men, in the execution of the simplest movement in the more advanced science called minor tactics. There is a fascination about the working out on a map, with a pointer, the puppet movements of assumed hostile bodies. The human beings who compose these bodies are not thought of. They do just as the drill books says they should do, so all bother from that direction is taken from the mind of the theorist and he goes merrily on reading, first how to fight a company, then a battalion, then a regiment, then a body composed of all arms. In the meantime his opinion of the art of making the solution of these problems possible grows more and more uncomplimentary, and the real education of the soldier is left to those who are regarded as unfit for anything beyond the duties of a taskmaster.

All masters of their art acknowledge that the more the extended order becomes our battle formation, the more important will practice in close order movements become as a means of training for the individual soldier. Just as the one order becomes more necessary to us, so the other at the same time gains consequence.

The value of the solidity of the battalion column, of readiness in passing from one formation to another, of individual dexterity, increases in like proportion to the necessity, under difficulties, for change from the one to the other form of battle. The so-called "close order drill," that is to say, the habit of more complete order and subordination at any given moment, will therefore gain importance from the new requirements of tactics.

Von Scherff says: "The power of moving surely and with cohesion in close order stands first and foremost as point of departure, and also as keystone of all action in battle. The ability to pass quickly from one form of close order to another and again to change from close to extended order and *vice versa* come next. Mobility, attention to orders, fire discipline, constitute the third requirement. . . . Lastly, a general acquaintance with the forms and requirements of outpost duty. These," he says, "will make infantry equal to every emergency of the greater operations of war." If all this be regarded as an inferior occupation for an officer, and avoided as too insignificant for the students of the higher branches of the art, then when the trial of strength comes those soldiers will be found wanting whose training and drill have been conducted unintelligently or neglected altogether.

What we must demand of the soldier is discipline, born of high personal energy. We must require of him a perfect familiarity with the use of arms. We should seek to develop his skill in taking advantage of the ground. Theorists cannot or will not do these things, but the practical soldier knows the full meaning of it all, and will make this work his first care.

Foreign drill books give brief directions how to work on a man's imagination. They are confined to a few simple principles for fighting, and are calculated to sharpen his wits and raise his self-respect. To the credit of our Board be it said no such gratuitous suggestions were made in the Regulations. To any one who has served in any army of the United States, regular or volunteer, a cure for excessive imagination and exuberant wit in our men would have been looked upon as the more necessary. No one has yet been able to give a good recipe for the production of *morale*, so our new book does not attempt it.

Boguslawski says: "A few great principles must be plain to all. These are that rules should be few and brief, as an attack must be made unswervingly and without hesitation; patriotism must be awakened by means of instruction; officers must give an irreproachable example, both in conduct and bearing, and they must raise the soldier's self-respect by treating him as an honorable man. If these ideas be carried out so far as is compatible with rigid discipline, much will have been done to develop military virtues in the soldier and to prepare him for the great tragedy of battle. The soldier must be mentally

and physically trained for war. Ingrain such training, and make it his second nature, even in the heat of battle, to keep touch with his officers and comrades. At the same time cultivate the man's mental powers and teach him to think for himself. War and the whistle of projectiles have a serious effect on the nerves of most men. So great is the instinct of self-preservation that some men completely lose their heads. The soldier must pursue his calling in the face of death. Such is his *raison d'être*, often forgotten during a long period of peace."

WEIGHTS AND MEASURES OF THE UNITED STATES.

By Prof. T. C. MENDENHALL, U. S. Coast and Geodetic Survey.

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The Customary Weights and Measures of the United States, that is to say, those commonly in use in this country, are either identical with or are derived from those which were lawful during the colonial period. Of necessity, then, they are almost entirely of English origin.

The Constitution gives Congress power to establish a system of weights and measures and to fix standards of the same. In the early days of the Republic much interest was shown in this subject by the most eminent men of the time; prominent among these may be mentioned George Washington and Thomas Jefferson, each of whom earnestly recommended action by Congress in this direction, the latter having devised certain very notable improvements in the system of weights and measures then in common use. The subject received the attention of Congress and the Executive Departments from time to time, but up to about the year 1828 there was no legislation upon the subject. In the meantime it became necessary for the Executive Departments of the government to establish some system of standards of length, mass, and capacity, in order that they might be governed thereby in the collections of customs and taxes.

The Treasury Department being most largely concerned with these matters, the question of providing and fixing standards was early confided to Mr. Hassler, the first Superintendent of the Coast and Geodetic Survey, and from that time to the present the Superintendent of the Coast and Geodetic Survey has been the Superintendent of Weights and Measures.

For the use of this Survey in its early operations Mr. Hassler had brought from Europe early in the century a brass bar, a part of which became and was for many years the unit of length adopted by the Treasury and other Executive Departments of the government. Congress not having acted upon the subject of weights and measures, the matter was left in the various States to local and legislative control,

and consequently the practice was exceedingly irregular. In many States, indeed, units of length and mass and other standards were merely traditional, and had no force based upon legislative action or other higher authority. While such confusion as existed might be tolerated in ordinary private commercial transactions, Congress saw that it was wise to establish at least a standard of weight which might be used in determining the mass of coins. This led to the passage of the act of May 19, 1828, which is the first, and indeed almost the only definite act of Congress upon the subject of weights and measures. This act provides that a certain piece of brass, now known as the Mint Troy Pound, should constitute the standard by means of which the coinage of the United States should be regulated. This standard, judged according to our modern ideas, is exceedingly imperfect, both as to its form and as to its construction. It is not solid, and consequently it is impossible to determine its density with any degree of accuracy, and hence the effect of variations of barometric pressure upon its weight must remain unknown. It was a copy, and doubtless a very precise copy, of the British standard troy pound then in use. This British standard, however, was a few years later destroyed in the burning of the Parliament House, and a new standard pound was constructed to which reference will be made later.

Although Congress was apparently unwilling to legislate in order to secure and require uniformity of weights and measures throughout the country, it seemed to be not unwilling to encourage this uniformity, and the next act, which is that of June, 1836, is of that character. It provided that a full set or a copy of all the standards of weight and measure which had been provided by the Treasury Department for the use of the Customs Service should be prepared at the Office of Weights and Measures and delivered to the Governor of each State in the Union. This was accomplished by the Superintendent of Weights and Measures during the next few years, and the action went far to secure uniformity in the customary weights and measures by the fact of the adoption of these material standards as received by the respective States for the standards by the Legislatures thereof. Some of the States had previous to this time adopted standards which differed slightly from these of the Treasury Department; but in all cases after a few years such legislation was repealed, and the standards adopted by the Executive Departments of the government soon became practically the standards for the whole country. Of these the primary units were the yard and the pound.

As a good deal of confusion has existed from time to time in regard to the relation of these units to the corresponding units of the British government it may be well to refer briefly to this relation. It has already been stated that the yard adopted was the distance between two lines drawn upon the scale brought over by Hassler about the year 1813, and known as the Troughton scale. It is true that the length of this yard from time to time has had different relations to that of the British yard, owing entirely to the temperature at which the comparison has been assumed to be made. It has probably never been the policy of the Office of Weights and Measures, however, to have a real outstanding difference between this yard and the English standard. As there is not and has never been legislation regarding the temperature at which this standard is to be accepted, it is clear that it is wise to fix the temperature at such a point that it may be equal as nearly as possible to the British standard yard, provided, of course, this may be done within a reasonable range of temperature at which comparisons may ordinarily be made. At 62° Fahrenheit, at which the yard was for a long time assumed to be a standard, it was found upon comparison to be longer than the English standard, that is to say, the present Imperial standard yard, and it was therefore determined to alter the temperature at which it was considered to be correct by reducing it to 59.6 instead of 62, at which point it is, as far as can be known, in accurate agreement with the present Imperial standard of Great Britain. It is hardly necessary to say that these two standards have never been compared directly with each other, but by means of copies of the Imperial standard which have been furnished the United States by the British Office of Weights and Measures.

The standard of mass adopted by the Treasury Department, and in virtue of the copies distributed under act of Congress becoming the standard for the States of the Union, is the avoirdupois pound which was derived from the mint pound already referred to. As stated before, this mint pound was a copy of the British troy pound of 1758, and as the new Imperial avoirdupois pound of Great Britain is derived from the same standard it may safely be said that there is little outstanding difference between the avoirdupois pound of Great Britain and that of the United States. In fact, certain comparisons by means of intermediate standards show this difference to be so small that it is the practice of the Office of Weights and Measures to assume the two pounds to be identical. Thus it may be properly declared that the

yard and pound of the United States are practically identical with the yard and pound of Great Britain.

Capacity measures were also adopted at this time by the Treasury Department, consisting of the wine gallon and what is known as the Winchester bushel. These are theoretically derived from the standard of length, the former containing 231 cubic inches and the latter, the bushel, containing 2,150.42 cubic inches. These are old colonial standards, and differ considerably from the present standards of capacity of similar names in use in Great Britain.

The origin and growth of the metric system during all of these years is familiar to everybody. The superior character of this system both as to simplicity and scientific precision was recognized at an early day by those who gave attention to the subject of weights and measures in this country, but as it did not seem for a considerable time at least that this system, notwithstanding its great excellence, was likely to receive general international approval, or even locally the approval of the French nation, no very serious movements took place towards its introduction in this country. A little after the middle of the present century, however, it became evident to all intelligent observers that this system was destined to become in time, and at no very distant time, the great international system of weight and measure. It had already come into extensive use among scientific men of all nations and even among English-speaking people, and serious efforts began to be put forth to secure its recognition by legislation in Congress. The result of this agitation of the question was the passage of the very important act of July 28, 1866, in which the use of the metric system of weights and measures is authorized and made lawful throughout the United States of America. In the same act a set of tables was adopted as establishing in terms of the weights and measures now in use in the United States the equivalents of the weights and measures expressed therein in terms of the metric system.

Although incomplete and unsatisfactory in itself, this legislation is, and in great degree for that very reason, most important and far-reaching in its results. At about the same time, in order that the practical use of this system might be encouraged and aided, Congress passed a joint resolution authorizing the Secretary of the Treasury to distribute to each of the States of the Union a set of Metric Standards of Weight and Measure, and at a later date similar sets together with the standards of customary weight and measure were distributed

to all of the colleges of the country founded upon the National Land Grant.

In the meantime it was discovered that the copies of the metric standards which were in use in various parts of the world by different nations were not in perfect agreement with each other, and that their relation to the original prototype metre and kilogramme was not known in a manner satisfactory to the requirements of modern science. Indeed, the original prototypes themselves, the metre and kilogramme of the Archives, were not constructed with that perfection and precision which was possible by modern methods, and did not themselves meet the requirements of modern metrology. The use of the metric system was spreading rapidly throughout the world, and it became important that the entire system of standards should be revised in a proper manner, and to this end an international commission was organized at the invitation of the French government. The result of this was the final establishment of a permanent International Bureau of Weights and Measures near Paris, which is supported by contributions from nearly all the civilized governments of the world and controlled by representatives of these same governments.

After nearly fifteen years of labor, including much original investigation and research relating to the principles which should control standards of weight and measure and many experiments as to the best methods of constructing and intercomparing such standards, the International Bureau had, in 1890, successfully completed the preparation of a considerable number of copies of the original metre of the Archives and of the original prototype kilogramme. These had all been compared with the original standards and with each other with the very highest degree of precision attainable by the best modern methods, and their differences, while small, were known with a great degree of accuracy. That metre which agreed most nearly with the metre of the Archives, and that kilogramme which agreed most nearly with the kilogramme of the Archives, were selected as the great international prototype units of length and mass. The other copies were distributed by lot to the various contributing nations, and thus the United States came into possession of two copies of the metre bearing respectively the numbers 21 and 27, and two copies of the prototype kilogramme, bearing the numbers 4 and 20. The first received at the Office of Weights and Measures in Washington were the metre No. 27 and kilogramme No. 20, these having been carried from Paris with

great care by special messenger. The seals upon the cases containing them were broken and the standards examined on the 2d of January, 1890, by the President of the United States, Benjamin Harrison, in the presence of the Secretary of State, James G. Blaine, and the Secretary of the Treasury, William Windom, all of whom attested to the identity and condition of the standards referred to. In virtue of a certificate to this effect, signed by these three distinguished officials, these standards have become the national prototypes for the United States.

In reference to these prototypes, action has recently been taken by the Office of Weights and Measures, which, while practically it has little or no bearing upon the value of the customary weights and measures in this country, yet from a theoretical standpoint must be regarded as of great importance. Referring again to the act of July 28, 1866, it will be remembered that in virtue of this legislation the use of the metric system was made lawful throughout the United States of America. No such action has ever been taken by Congress in reference to the customary system of weights and measures, and the authority of the yard and pound to-day rests entirely upon local legislative action. It will thus be seen that by the act of 1866 the metric system in the United States is placed upon a basis entirely different from and indeed quite superior to that of the customary system of weights and measures. Indeed, it is the only system of weights and measures which has ever been made lawful by act of Congress, and in this the use of the mint pound according to the act of 1828 is not excepted, for that was made lawful only for purposes of coinage. It has already been stated that the act of 1866 contained certain tables giving the equivalents of the weights and measures as ordinarily used in terms of the metric system. Nowhere in this act is the metric system defined. It must therefore be assumed that the word "metric" is used in the sense in which it is universally used throughout the world when applied to a system of weights and measures, that is to say, that the system referred to is that in which the metre and kilogramme of the Archives, or now the international prototype metre and kilogramme, are the standards of length and mass.

As Congress has never in any manner defined a yard or a pound, or adopted any material representation of these units, the best that can be said for them is that the words are to be used in the ordinarily

accepted sense. We have on the one hand, therefore, a system of weight and measure which has received the approval of nearly the entire civilized world, the fundamental standards for which have been constructed in accordance with the highest requirements of metrological science and which has been authorized and made lawful for the whole United States by special act of Congress. Further than this, Congress has for many years authorized and sustained the participation on the part of the United States government in all the operations of the International Bureau of Weights and Measures, in which the metric system was being and is being perfected and perpetuated.

On the other hand we have a system of weights and measures whose only recommendation is that it has been for many years in customary or common use. It is irrational in theory, irksome in practice, and has been condemned by all who are competent to speak upon a subject of this kind. Furthermore, it has never been authorized or made lawful by act of Congress, and as a matter of fact is almost without recognition in the history of congressional legislation. It has been determined by the Superintendent of Weights and Measures that a proper and wise recognition of these facts justifies, if it does not demand, the acceptance of the international prototype metre as the unit of length, and the international prototype kilogramme as the unit of mass — their representative material standards now in the possession of the government being utilized for such comparisons as may be deemed necessary and expedient. This implies that the yard shall hereafter be defined as a certain fraction of a metre, and that a pound shall be defined as a certain fraction of a kilogramme, and this will be the practice of the Office of Weights and Measures henceforth.[1] While not interfering in the slightest degree with the practical or commercial use of the yard and the pound, there are very important theoretical and scientific advantages in thus referring these units to the great international prototypes, which are already the standards of length and mass for the greater portion of the civilized world. It is hoped, therefore, that this action will meet with the approval of all who are interested in the advancement of the science of metrology and in the increase of precision in both theoretical and applied science.

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[1] These definitions, according to the act of 1866, are as follows:

$$1 \text{ yard} = \frac{3600}{3937} \text{ metre.} \qquad 1 \text{ pound} = \frac{1}{2.2046} \text{ kilogramme.}$$

LIGHTNING AND STRONG CURRENT ARRESTERS AS USED FOR THE TELEPHONE.

By I. H. FARNHAM.

Read December 8, 1892.

When Franklin proposed to erect lightning rods which would convey the lightning to the ground, and so protect buildings to which they were attached, there were not wanting superstitious people who proffered all sorts of warnings. Some argued that it was "as impious to ward off heaven's lightnings as for a child to ward off the chastening rod of its father." Others went to the opposite extreme and concluded that if there was any impiety about lightning rods it lay in the fact that they invited the "chastening rod," and that it was madness to "tempt Providence" in any such way.

The foregoing is substantially one of the records given in connection with the first attempts to prevent the danger of the lightning's stroke as long ago as 1752 (Age of Electricity). From that time to this the sons of Franklin have been seeking the best means of diverting the discharge of nature's great "Leyden jar" away from people and property.

The necessity of protecting telegraphic instruments from lightning was forced upon the pioneers in this art, and considerable ingenuity was exercised in those early days upon the problem. It will be interesting before passing to the direct subject of the evening to glance at these earliest forms of protectors.

The first lightning disturbance on electrical instruments was noted on the telegraph line laid down at Göttingen in 1833 or 1834. It was ten years later, however, that Professor Morse, encountering the same troubles with his first line, was compelled to cast about for some remedy.

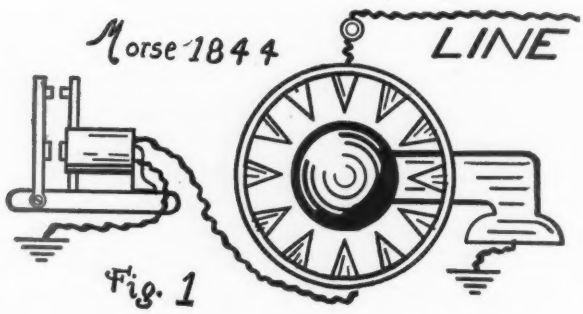


Fig. 1

Among other devices of his was that shown in Figure 1. It consisted of a brass ball, surrounded by a metal ring, which ball was connected with the ground. The ring had on its inner surface a number of small points projecting towards the ball, but not in contact with it; it formed a part of the line circuit.

In 1846 the American Philosophical Society called the attention of Professor Henry to the subject. He made careful deductions from his study of the difficulty, and to him is credited the plan of running a wire from a ground plate up the telegraph pole and ending it about a half inch directly beneath the telegraph wire, as shown in Figure 2.

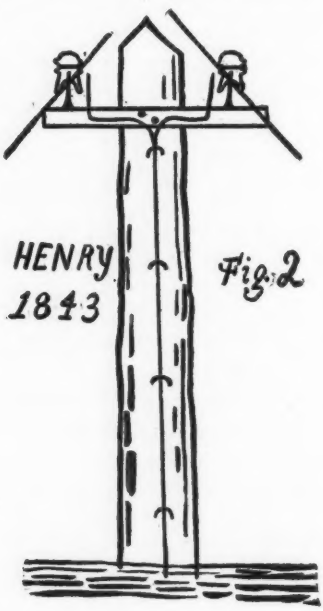


Fig. 2

This method of protection is employed to-day on many lines, though it serves only to arrest the very heavy discharges, the space between the end of the ground wire and the line wire being too great to take away ordinary or, to the instruments, even dangerous discharges.

Steinheil, in 1846, used metal plates 6″ in diameter, separated by thin silk cloth; these plates were placed on the roof of the station and protected from rain by a wooden box. This arrester proved quite satisfactory.

In 1847 a French electrician, Brequet, proposed using a very fine wire from the station to the main line, 15 or 18 feet distant. This was expected to fuse on the passage of lightning, and thus arrest it before entering the station.

Those early workers in the electrical field had only nature's lightnings to guard against, while we meet to-day a much more difficult problem in guarding our delicate apparatus from many forms and degrees of strong currents down to the well-named "sneak" current, which steals in over all the early forms of protectors and silently consumes the apparatus.

It is the combination of difficulties found in guarding against this wide range of troublesome currents, without at the same time rendering the instruments insensible to their legitimate currents, as well as to outline the results so far accomplished, particularly as applied in the telephone field, that interests us to-night.

There are now about 350 different American patents on lightning and heavy-current protectors. We will mention only a few characteristic forms. They may be divided into several different classes, each class embodying individual and distinct features. There are forms which open the line circuit, and so shut out the dangerous current; and others which offer to the heavy current a shunt or bypath around the instrument to be protected. Again, they could be divided into single-acting and multiple-acting; that is, devices which after being operated are automatically readjusted for further service, and those which require manual resetting.

I prefer, however, to arrange them in four classes, as follows:

1. Air space, or spark arresters.
2. Fuses.
3. Magnetic Devices.
4. Thermostatic Devices.

Some protectors embody more than one principle in their operation, and so cannot be strictly confined in any one of these classes.

The "*air space*" *arresters*, the first class, include Professor Morse's ball and pointed ring and Professor Henry's wire ending at a point near the line on a pole; also the plate arrester as modified by the silk cloth of Steinheil, and the paper separators of other inventors — a large variety of forms well adapted to divert lightning from the lines to the earth. One form, a two-plate arrester in common use by telegraph companies, has brass line plates separated from a brass ground plate by a rubber ring about $\frac{1}{32}$ inch in thickness, allowing an air space between the line plate and the ground plate through which the high potential charge of atmospheric electricity passes as a spark. [In the model shown several spots could be seen where the brass had been fused by the discharge.] In fact, it is the liability of the metal plates fusing together and thus intercepting the passage of the working currents that has induced many persons to try other means of protection. The insertion of varnished or paraffined paper between the plates sometimes, but not always, prevents the fusing of the metal together.

In several other forms paper is used between plates; an arrester having a heavy copper rod set into a groove in a wooden base, with strips or plates of brass held against the rod, separated only by thin paper, has proved a very efficient lightning arrester. I have sat during a thunderstorm in a wire tower having 400 lines passing through a set of these arresters, and was interested to hear the little discharges take place, now on one line and again on others, sometimes accompanied by the lightning flashes which evidently caused them.

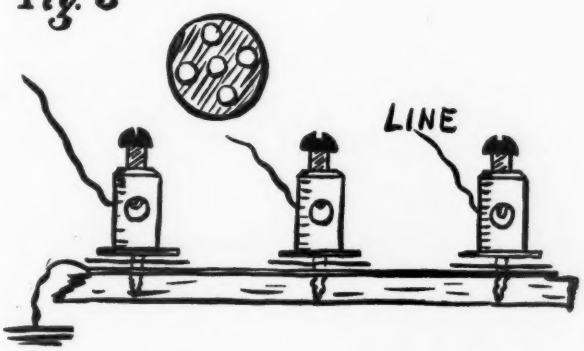
In other forms, again, these arresters have points on one or both plates. Arresters provided with such points are supposed to be superior to those having plain surfaces, but in practice it is difficult to discover the advantage.

It should be remembered that air space arresters in order to be effective must have a very small space through which the discharge is to take place. Failure to recognize this fact has caused the loss of many instruments, and was the reason that Professor Morse and Professor Henry's air space arresters were not as satisfactory as hoped. It is for this reason, too, that many of this class of arresters, having paper or cloth separating the disks or plates, have proved more satisfactory than the strictly air space form. In the latter, manufacturers and

users have failed to place the plates or points near enough together, fearing actual contact.

The high potential current will spark across the air space more readily than through paper or other material; hence, other things being the same, the purely air space is the better, though, as has been stated, until very recently the paper-separated plates have proved more reliable in practice, on account of the very small separation of the line and ground.

Fig. 3



The arrester shown in Figure 3 combines the advantages of both the purely air space and the forms having paper separators. It was designed by a Mr. Bowers, of Fitchburg, Massachusetts, and probably was the first to embody the use of perforated paper or other insulating material between the arrester plates. This arrester has done good service, as can be seen from an examination of a strip of plates which has been in practical use. It is interesting to note that the discharges have taken place in every instance through the openings in the paper and not through the solid body of it.

Let us now look at a modern air space arrester constructed on the principle of the one just examined, but possessing several advantages over it. The plates are of carbon, and therefore non-fusible. Having a roughened surface, they contain whatever advantages there are in point arresters. The plates are separated by a sheet of perforated mica. The mica is of such a thickness (about .0035 inch) as to allow a discharge to take place across the space when the difference of potential between the plates reaches or exceeds 300 volts. This

arrester has been constructed in several forms. It was found in service that occasionally particles of carbon dust were dislodged from the plates at the air space, thus connecting them together. The arresters are now so constructed that the plates may be readily withdrawn from the clips which hold them in position.

The "*fuse*," our second class, was suggested first by Brequet, in 1847, as a lightning arrester. A fuse has little value as a protector from lightning; the discharge being so sudden and disruptive that by the time the fuse has operated the enemy has struck the fatal blow and vanished.

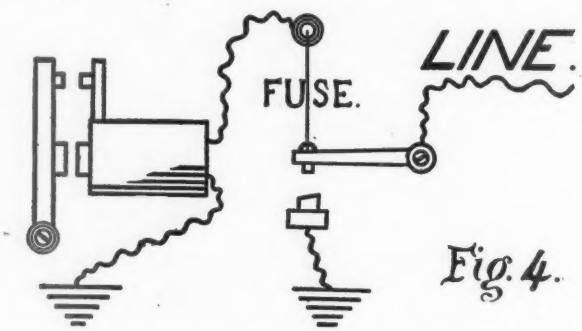


Fig. 4.

Figure 4 shows an arrangement of fuse and lever designed to open the main line from the instrument and connect it to the ground in season to save the instrument and dispose of the lightning discharge. Quite a number of arresters have been devised on this principle. Such apparatus is "too slow" for lightning.

Fuses, however, have found their value in protecting against continued currents — such as are diverted from electric light and power wires.

Of fuses in common use, the "Vail," consisting of a very narrow bit of tin foil protected in a hard rubber tube, and mounted to be easily replaced by a fresh tube and foil, was one of the early forms employed by the telephone companies. It was intended to operate with about $\frac{1}{2}$ ampère of current. This protector was very useful in cutting off heavy currents, but was found wanting in two essentials. First, it would often allow a current just strong enough to destroy an annunciator on the switch board to pass it, while very small atmospheric discharges, too feeble to cause any trouble whatever to the apparatus, would open the fuses by the score.

The "Hibbard" protector — a foil wound up in asbestos paper and held between German silver clips, has also been much used, and has saved many offices from damage and possible fire, but is found to have the same objections as presented in the "Vail." German silver wire of very small diameter has been used to a limited extent, sometimes being stretched through glass tubes.

A form of protector embodying both the fuse and plate arrester has been used. It consists of a fine copper or German silver wire wound about a metal rod; the wire forms a portion of the line circuit, and is separated from the rod by paper or other thin insulating material, the rod, of course, being connected with the ground.

The third class comprises a large variety of "*magnetic devices.*" Some are designed to open the line, while others shunt the instrument to be protected through a heavier wire, usually that around the protector magnet itself. The use of the magnet has been an inviting field for protector inventors, as by its use, and scarcely by any other means, has it been deemed practicable to construct an automatically restoring protector for continuous heavy currents. Figure 5 fairly

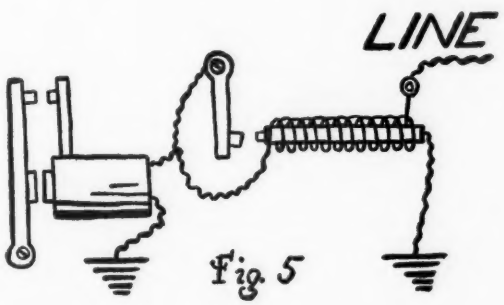


Fig. 5

illustrates one of these arresters designed to shunt the instrument through the comparatively coarse wire around the protector magnet. It will be understood from the illustration that the ordinary working current will not operate the armature of the protector. A heavy current, however, will bring the protector armature against the contact point placed on the magnet core and form a shunt around the telephone or other instrument to be guarded. This instrument is sometimes modified by being provided with two or more distinct coils of wire, each one differing in sensitiveness from the others, the object being

to cause the armature located in front of the coil, having many turns (necessarily small wire), to operate with moderately strong currents, while the armature of the coarser coil and less number of turns responds to currents that would endanger the smaller wire. Figure 6 is intended to show a form of this instrument. The "Cartwright" protector presented is constructed on this principle.

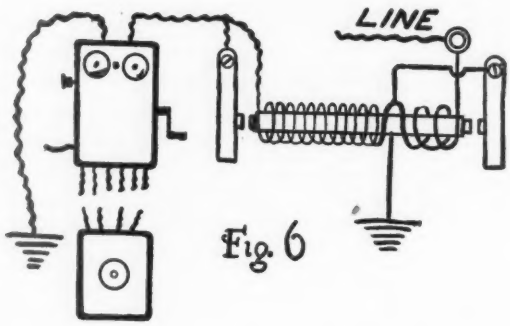


Fig. 6

When arc light circuits were the only ones liable to come in contact with wires conveying feeble currents the form of protector just described was quite satisfactory; in fact, it was extensively adopted for electric fire alarm systems. It is readily understood that this protector is self-restoring or multiple-acting, because the moment the abnormal current ceases the protector armature returns to its usual position. Arc light dynamos automatically adjust themselves to deliver a current limited to nine or ten ampères, and this would not endanger ordinary office and line wires, or even the wire used in the form of protectors just described; but this is not true of railway and other power dynamos, which may yield a volume of current sufficient, if allowed to continue, to destroy any wire employed either in the protectors themselves or the connecting lines. For this reason wherever this form of protector is used to-day it becomes necessary to add a fuse wire in the circuit to protect the protector itself against very heavy currents.

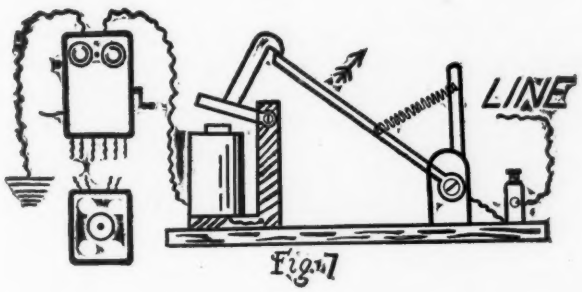


Fig. 7

A magnetic device for opening the circuit is shown in Figure 7. There are a number of similar forms. This is called the "Plush," from its inventor, Dr. Plush, of Philadelphia. It is extensively used by the telegraph, and to a limited extent by telephone companies. As a protector from dangerous currents which continue upon the line until they are interrupted it works admirably. Its weakness lies in that, when it is so adjusted as to operate with moderately dangerous continuous currents, it is operated by discharges of lightning so small as to cause no danger; and, as it is not multiple-acting but leaves the line open until manually reset, frequently occasions delay. Located on grounded lines in central offices, where attendants are always at hand, it is a good protector.

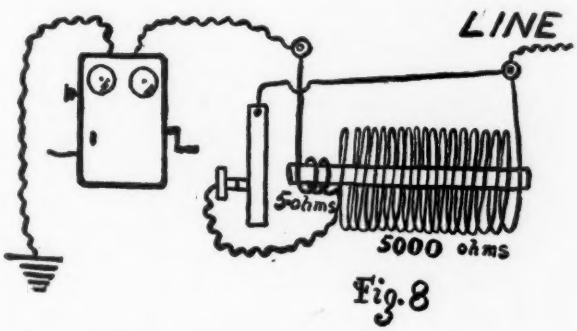


Fig. 8

Figure 8 illustrates the operating principle of an ingenious protector brought out by Mr. Clauson, of Boston. It might be termed a compromise between the last two forms described. To a great extent

it has the advantages of both, without the faults of either. The magnet is surrounded in this case by an ordinary coil of copper wire supplemented by another coil of very high resistance. The armature, when standing in its normal position, shunts the high resistance coil from the line circuit. When, however, a heavy current passes through the low resistance coil the armature is moved forward, thus bringing instantly into the circuit the high resistance coil, which by its resistance reduces the dangerous current to an amount safely carried even by its own fine wire. There is at the same time sufficient foreign current allowed to flow to retain the armature in the "safety" or protecting position. When the source of the dangerous current is removed the armature automatically returns to its back stop again, shunting the now unnecessary resistance from the line. Mr. Clauson has constructed several modifications of this protector, in one of which he employs carbon resistance.

It would seem at first thought difficult to construct a magnetic device which would not be responsive to lightning discharges and yet would operate with the much feebler currents, even "sneak" currents. This has been accomplished, and is illustrated by Figure 9.

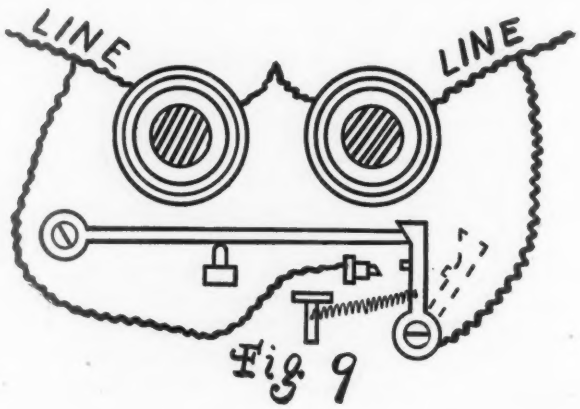


Fig 9

The electro-magnet shown in this figure is supposed to be the regular working magnet of the instrument to be protected — a telephone bell, for instance. Beneath, or at one side of the magnet, is fastened an auxiliary armature, so adjusted that it will not respond to the working currents but will move upward with stronger currents.

In its normal position this armature prevents a lever from answering to the gentle pull of a spring and moving forward against a contact point so connected as to shunt out the bell when the contact is established. If now a cross occurs with a light or power wire the armature moves, releasing the lever, and the protection is accomplished. It will be noticed that the form of the armature end and of the lever which rests against it are such that, on the quick upward movement of the armature, the lever is thrown back for a moment, and by this backward movement allows the armature to return in season to catch the lever before it has had time to pass under the armature. This would occur if the discharge through the magnet coil is momentary, as is the case of usual lightning discharges. Figure 10 shows this protector after it has operated by a continual dangerous current.

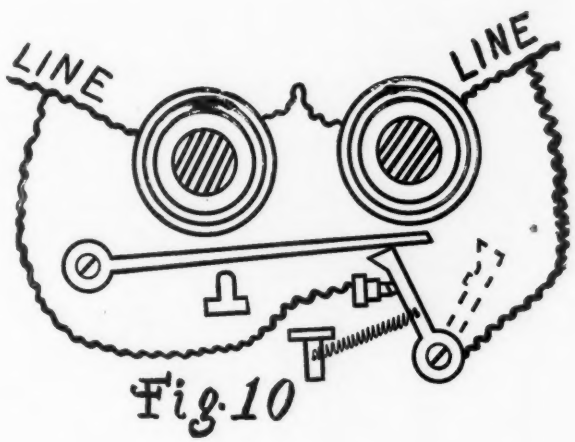
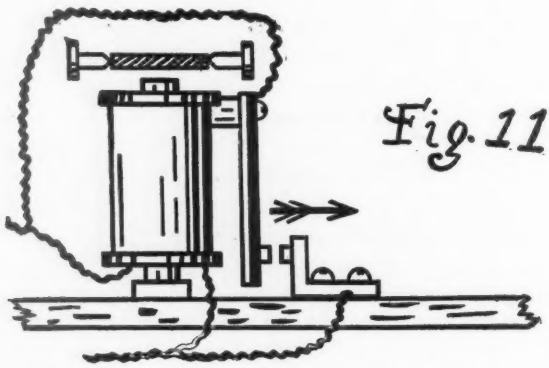


Fig. 10

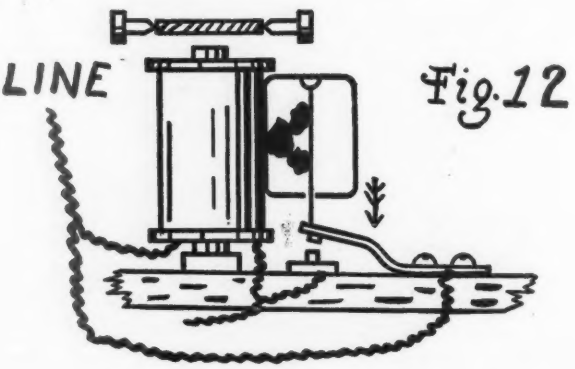
A protector, resembling in construction a pile driver, has been devised by Mr. Morse, of Cambridge, Inspector of Wires for that city, and is in use on some of the city lines. The hammer is released by the magnet when excited by a heavy current. In falling it closes a shunt around the instrument and puts a ground on the circuit. It is novel in construction, but in principle like some other forms operated by the magnet.

The fourth and last class embraces "*protectors operated by heat.*" They are admirably adapted for detecting and arresting the so-called

"sneak" currents, while at the same time they are free from the objection of being affected by ordinary lightning discharges. A few forms are illustrated. Figure 11 is a thermostatic bar placed close



beside the working magnet of the instrument to be guarded, arranged to move backward when warmed above 100°, establishing a contact which shunts the instruments. It is automatic, but too slow in operation for any other than the smallest objectionable currents. Figure 12



shows a small metal tube or box placed against the coil of the magnet; through this box passes a thread which normally holds a flat spring away from its shunting contact. Within the metal box is also placed a little composition — not unlike that used upon the end of a friction match. The undue heat of the magnet when exposed to foreign cur-

rents ignites the thread and allows the shunting spring to operate and cut out the instrument. This reminds one of the tales of Western prairie life, where, to save the home from destruction by the oncoming prairie fire, the mother, alone and realizing the peril, catches a match and lights the grass about the cottage, beating it back and controlling it until it has diverted the prairie flames. It is fire to prevent fire.

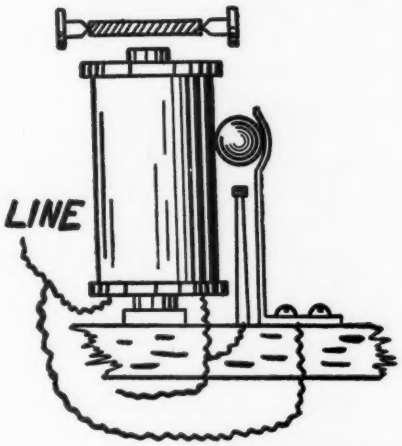


Fig. 13

Next, we have in Figures 13 and 14 two forms of the "wax ball" protector; one for shunting the instrument, the other for widely opening the line.

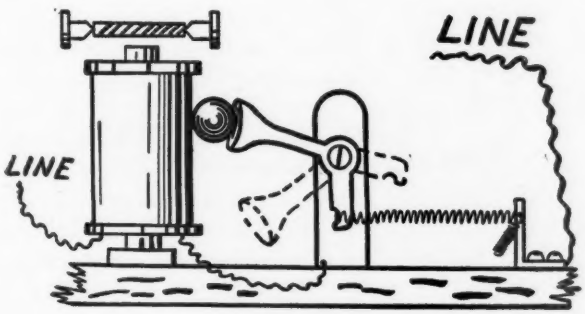


Fig. 14

A wax ball is held against the magnet coil of the instrument to be protected by the gentle pressure of a spring. Upon passage of a current of sufficient strength to warm the coil the wax softens, allowing the spring to move toward the coil until it makes contact with another spring or stud, the spring pressing the wax ball, and its contact being so wired that when there is a connection established between the two a shunt circuit is formed around the instrument. In the other form the movable wax ball support releases a spiral spring, which instead of shunting the instrument opens the main circuit widely, thus interrupting the dangerous current.

The particular advantage of this protector is sensitiveness to continuous currents which are only strong enough to endanger the finest magnet wire, while at the same time it is not troubled by lightning discharges. Other advantages are no extra magnets, resistance, or connections in the working circuit.

As already pointed out, a fuse to protect from such a current requires to be extremely sensitive, carrying not more than $\frac{1}{4}$ or $\frac{1}{3}$ of an ampère, and from its delicacy would be very frequently destroyed by discharges too feeble and of too short duration to be of any danger to the apparatus.

There are protectors in which the fuse wire is coiled upon itself for increasing its sensitiveness to the heating effect of the current. These are not simple fuses, so I have classed them with the thermostatic devices.

Having described and shown only a few of the characteristic protectors designed for telephonic as well as other delicate electrical apparatus, allow me in a few words to explain how the telephone instruments in this vicinity are protected at the present time. The aim has been to protect from the whole range of dangerous currents, both "direct" and "alternating" in character, including instantaneous disruptive discharges, long continued heavy currents, and those only just strong enough to do harm.

It has been the aim, also, to protect a metallic circuit from electrical charges which would be dangerous to persons, and which might not under certain conditions be dangerous to the apparatus. In exchanges where all these hazards exist there is employed at the telephone subscribers' stations a combination of three arresters heretofore described.

1. The wire as it enters the building is attached to a simple lead fuse six inches in length, protected in an asbestos-lined box; this fuse

will melt at six ampères of current in ten seconds, and is sufficiently sensitive to prevent danger of overheating the leading-in wires, while it will not be troubled by ordinary atmospheric or lightning discharges.

2. Near the fuse, between it and the telephone instrument, is placed an air space carbon plate arrester, operating at a difference of potential of 300 volts and upwards. This arrester is usually located within the box which incloses the fuse. See Figure 15.

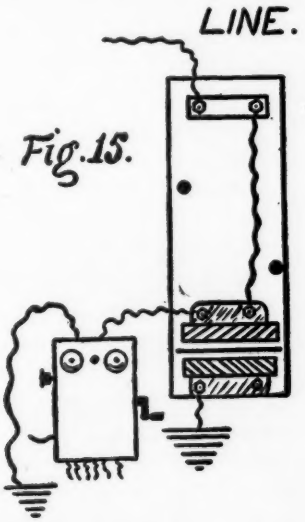


Fig. 15.

3. A thermostatic device for taking care of the weaker currents is combined with and located near the fuse, or in many cases is applied to the bell magnet, and then is known as the "wax ball" protector.

The carbon plates contain within an aperture near the inner surface a disk of fusible alloy for destroying a continuous arc, and thus preventing the danger of fire from this source. This would happen only when high potential currents of too small quantity to open the fuse were present.

The protectors in use to-day have been the subject of much study and have undergone many modifications. Dr. Hayes and Mr. White, both well known to this Society, are credited with improving much of this apparatus, particularly that employed at the central offices. F. A. Bickernell, of New York, has accomplished much in perfecting this system of protection. The central office protectors are the same in principle as those at the subscribers' stations, the fuse being located

at the outer end of the cables, one on each wire; a "heating" or thermostatic coil and an air space arrester being placed at the office end of each wire as it emerges from the cable. In the central office protector, instead of using wax as the thermostatic portion, soft solder is employed, which upon melting allows a spring to move against a contact point and thus throw on a ground between the line and the switch board. When this happens the annunciator resistance (usually 500 ohms) is shunted, and the current generally increases sufficiently to operate the fuse; if not, it is too feeble to do further harm. Figure 16 illustrates the operation of this combination.

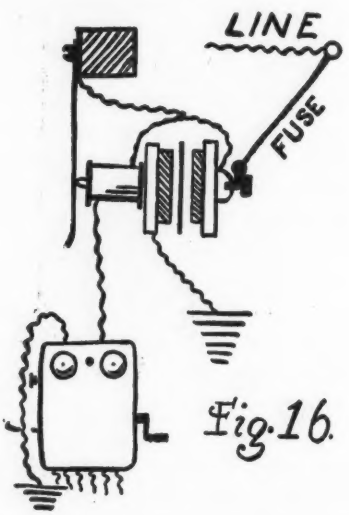


Fig. 16.

We find in practice some trouble with the air space arrester by its occasionally becoming grounded. It is not serious, however, as will be evident from the fact that in the Milk Street office, employing about 10,000 of these arresters, the average is about one trouble per day. The removal of this objection is being studied with good promise of a remedy. Observations of a large number of accidental contacts with electric light and power wires have confirmed us in the belief that as a thorough protection for telephonic apparatus this system has few, if any, equals.

[The operation of some of these protectors under widely differing conditions of current was then illustrated by tests made by use of currents of 100 to 500 volts furnished by the Institute dynamos.]

HEATING AND WORKING OF METALS BY ELECTRICITY.

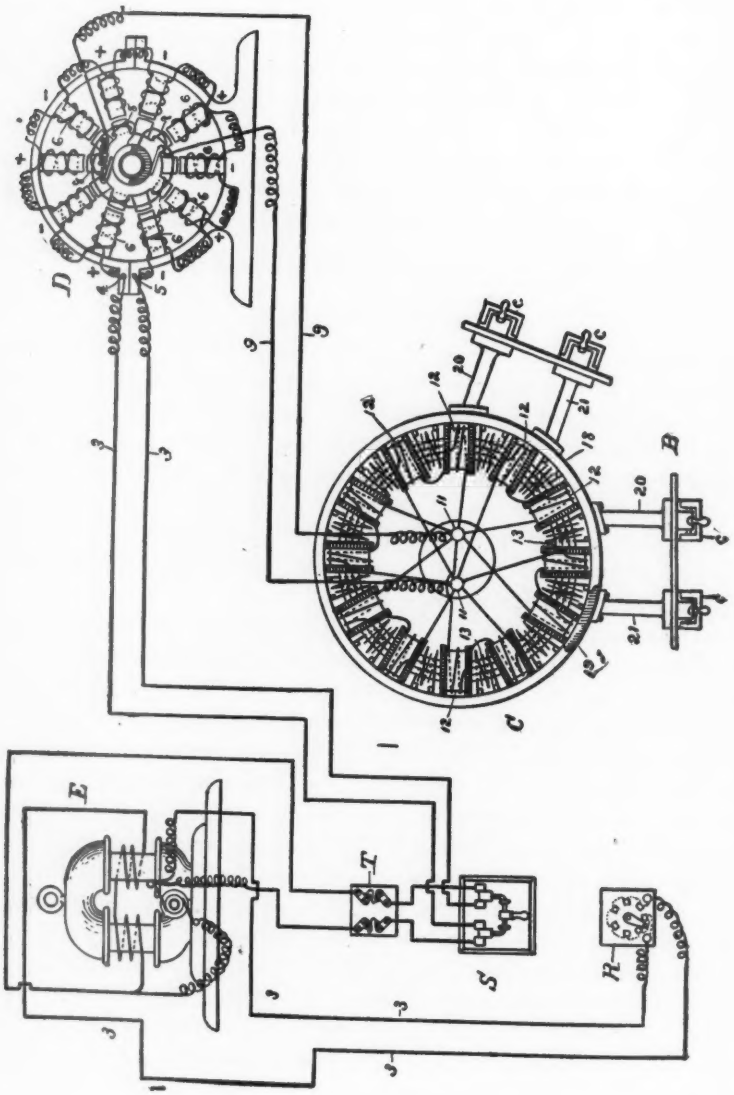
By GEORGE D. BURTON, President of the Electrical Forging Co.

Read December 22, 1892.

Accepting the invitation of the Society of Arts, I take pleasure in presenting some illustrations and description of my system of heating and working metals by electricity. By careful observation and numerous experiments I have succeeded in accomplishing some things which theory from high authority asserted could not be done. Some of you may say that you have seen in use before my time the same system that I describe. If so, I must ask you where, for I claim that this system is the first employed in working of metals successfully and economically in small, long, or large masses.

I was not the first to conceive the idea that metals could be worked by electricity. Johnson, in 1865, obtained a patent for heating and annealing wire by a current of electricity. Williams, in England, in 1881, obtained a patent for working metals by electricity, using a system of accumulators. Other inventors procured patents about 1870 for the process of working metals by a current of electricity. That the methods then employed for producing the current were too expensive was no doubt the reason why they were not successful.

The construction of our apparatus may be seen from the illustration, which shows the generator, exciter, converter, and regulator as they are connected when in general use and employed in operating this system. This metal-heating apparatus is designed to heat a bar of metal of any size or shape within the capacity of the machine; 108 cubic inches of metal have been heated at one time, with an expenditure of 47 electrical horse power. The generator shown is an alternating current generator, producing 1,600 volts and 24 ampères. Every other core of the armature of this machine is unwound — a feature which gives superior results.


D
C
B
E
T
S
R
3
9
1
2
11
12
13
18
20
21

The current generated by this machine is transformed into a heating current of low electro-motive force and great amperage, both of which vary according to the size of the piece of metal being heated, say from 4 to 30 volts, and from 6,000 to 10,000 ampères. The dynamo "D" has its fields energized by the exciter "E," which is a shunt wound machine, exciting its own fields. This machine produces 220 volts and 6 ampères. This current is variable. The voltage and amperage vary in like proportion as 6 is to 220. The regulation is obtained by the rheostat "R." This regulating device absolutely controls the heat at the terminals of the secondaries of the transformer "C," and so minutely that a piece of metal can be raised to a white heat and maintained at that point for a great length of time with very little power.

It is to be observed that there is no obstruction introduced into the high tension circuit of this apparatus, consequently there is nothing to retard the progress of the current in its passage to the transformer, which is used for changing the current. The transformer is constructed as follows:

"E" represents the core, composed of soft iron wire. About 800 pounds is used in this apparatus in small pieces, breaking joints, as shown, and uninsulated; "12" represents the primary coils, twelve in number, and connected to the dynamo current in series, each series in pairs, and each pair in multiple arc; "14" represents the secondaries, composed of copper spirals formed by casting. There are twelve of these castings, one end of which is bolted to the ring "19," which we designate as the positive pole. The other end of the casting is bolted to the ring "18," which we term the negative pole. These rings are composed of copper, and weigh about 600 pounds each. To these rings are bolted the metal holders "22," one upon each ring. The bar or rod "B" is placed between the holders "22," and completes the circuit between the two poles. The current is then turned on, and the metal bar is heated by the inductive action of the electric current produced by the transformer.

Should there be two pieces, each 1 inch square x 3 feet long, heating at two different points about this transformer, the dynamo "D" furnishes the required current to heat said bars in $4\frac{1}{2}$ minutes, with an expenditure of 43 electrical horse power. Should it be desired to heat three pieces, each $1 \times \frac{1}{2}$ inch square x 3 feet long, heating at three different points, the dynamo would furnish the required current, which would be 52 electrical horse power for $3\frac{1}{2}$ minutes.

It will be seen that no power is wasted. The transformer calls upon the generator to furnish only sufficient power to heat the pieces held within the metal holders.

If it is necessary to fuse a piece, it might be 15 inches long and 1 inch square, and be brought to a fusing point in $2\frac{1}{2}$ minutes with an expenditure of 42 electrical horse power. As soon as the piece is melted and falls from the metal holders the circuit at the terminals of the transformer is instantly broken and all the load at the same instant is removed from the generator, except what is required to overcome friction, which is less than 1 horse power, and this all takes place without changing any of the electrical connections. The construction and arrangement of the various parts of the apparatus cause each part to act automatically and in unison with every other part of the entire system. This feature is of great importance in the successful working of metals by the use of the electric current.

Suppose in a large factory it is desired to heat twenty bars at one time, *i.e.*, to keep that number heating, constantly removing a heated bar and inserting a cold one; the automatic adjustment of our apparatus permits this, and thereby meets the customary forge or heating furnace in its every requirement.

Some of the advantages of this process which show why it commends itself in a commercial way may be stated as follows:

1. Economy in the use of the current employed to heat bars of iron or steel of any size within the capacity of the apparatus.

2. The absolute control of the electric current during the period the bars are heating.

3. Economy in time, labor, and fuel over any other method of producing heat — no time wasted in attending the forge fire.

4. Cleanliness about the workshop — no smoke, dust, or ashes to be removed; no coal to be carried to the forges; more floor space to be utilized on account of a less number of forges necessary for the same work; and absence of the intense heat in the present forge shop.

5. The fact that electric heat is the cleanest. There are no gases introduced into the metal while heating, which is quite important in many cases.

6. The evenness of the heat within and without the entire piece or bar under heat. With electric heating, results are obtained in working a piece of steel which it is impossible to obtain if the bar is heated by any other known method. A steel hammer weighing $2\frac{1}{2}$ pounds

has been formed and completed at one heating. By the usual method it is necessary to reheat the bar from three to four times in order to complete what electricity will do in one heating.

7. The greatly decreased loss by scaling. This loss under the usual method of heat is from 6 to 9 per cent. The loss in scale by electric heat varies, if the piece is heated in open air, from 2 to 3 per cent.; if under cover, so that the atmosphere is nearly excluded while the bar is heating, it is less than 2 per cent.

8. All danger from an electric shock is avoided. The heating process is conducted with the same freedom and safety as by the ordinary methods.

The question may suggest itself, Why is it essential to employ our particular system of connecting up the apparatus, and why some method other than what we show would not produce the same results? It is possible to connect up the various parts used to make this complete heating plant in a number of ways, and fair results are obtained in the use of the varied connections; but there is no other system of all that I have tried which can be operated with so little power to obtain given results as the system here described.

Having explained in a general way the methods employed, and the construction and manipulation of the electrical part of this process, I will now come to the question of cost as compared with coal, as the matter of cost is generally the first question raised by all who take an interest in this subject.

Many people believe that the cost of electric heat is enormous as compared with the cost of coal, oil, or gas. The following figures on this point, taken from the report of Mr. George L. Harvey, the well-known mechanical engineer of Chicago, which was written after spending some time in making numerous tests at our works, may be of interest:

FROM THE REPORT OF MR. GEORGE L. HARVEY.

The heating apparatus has for its object: To heat a bar of metal of any size or shape up to the full capacity of the apparatus. This is done by taking an alternating current of great force and small amperage, and transforming or converting it into a heating current of low electro-motive force and great amperage. This current is applied to the ends of a bar, or piece, to be heated, and accomplishes the result in a minute or two. The clamps attached to the transformer hold the pieces to be heated.

Three tests were made to show the horse power required to heat given sizes of bars under various conditions, from which the cost of heating the test bars could be calculated and enable one to estimate the cost of heating different bars without an actual test.

The power in the generating room was provided by a 60 horse power motor, with an

Emerson power scale so attached that the horse power delivered to the dynamo could be determined at any time. Allowance was made for friction and power required to drive the generator when the transformer was not at work.

Other tests, made previous to my work, are tabulated, to give further data on which to base my conclusions. These, I understand, were all made by parties outside of the employ of the Electrical Forging Company.

I used in making my conclusions further tests, which show that:

1. The horse power required to heat a cubic inch of material is independent of the length of bar — an unexpected result.

2. The horse power required to heat a bar decreases very rapidly as the time of heating is shortened.

This is a peculiar result, partly accounted for by the fact that the radiating surface remaining constant less heat will be lost by radiation the quicker the piece is heated, and will, therefore, require a smaller "total heat or power" to bring a given bar to a white heat.

This fact is of great practical value, as the rapidity of heating determines the value of the heating plant, for if ten minutes were required to heat a bar in a forge, and but one in this machine, you save nine tenths of the total time of not only your machines but your men.

In working pieces in a forge several reheatings are sometimes necessary, while with work heated by electricity it cannot be doubted that a less number of reheatings would be necessary. This saving of time, amounting to several per cent., must be added to the saving shown below for the electrical heating process.

3. That pieces protected from the air while heating require less heat than when exposed, which would be naturally supposed.

Below I give an estimate on a 600 H. P. plant, which according to a bid made by the Electrical Forging Company is capable of heating a billet 1 x 8 x 36, containing 288 cubic inches, in one minute to a working heat.

These figures are given by them:

Cost of plant	$22,500	
Interest, 6 per cent		$1,350.00
Repairs, 4 per cent.		900.00
Coal at 2 lbs. per H. P. per hour, at $1.25 per ton.		2,250.00
Man to run generator		900.00
Helper for heating on transformer at $1.50 per day		450.00
Total yearly cost		$5,850.00

To which must be added the power plant for running the main generators.

Engines 600 H. P. Boilers, Pumps, Heaters, Piping Stack, Shafting Power House		$39,000.00
Yearly cost:		
Interest on $39,000	$2,340.00	
Engineer	900.00	
Fireman and helper	1,800.00	
Assistant engineer	700.00	
Insurance	400.00	
Ground lease	(?)	
Repairs	2,000.00	
Total yearly cost	$8,140.00	
Power plant	5,850.00	
Total yearly cost		$13,990.00
Total daily cost	$46.66	
Or for one billet at one billet per minute for 600 minutes, viz., a day	.0778	

The cost for heating a billet by coal in a shop would be as follows:

Billet 1 x 8 x 36, 288 cu. in.; weight, 80 lbs.

[1] Coal required, 36 lbs. at $1.65 per ton . . . . . $ .0252

The time required for heating this bar will be about ten minutes longer than the electric process, which will require, as claimed, one minute. Then we must add to cost of heating by coal, ten minutes.

One smith at 30 cents	$ .05
One helper at 15 cents	.025
Total cost for heating by coal one 80 lb. billet	.10
Total cost by electricity	.0778
Gain	$ .0222
If two helpers were required, the cost of heating billets would be, by coal at $1.65	$ .125
By electricity	.078
Saving	$ .047

The electric heat acting as it does from the inside and extending outward heats a bar in a far superior manner to any external heating, even if the external heat is free from sulphur or dirt.

The central core, if required, can be heated to a liquid state, and retains heat longer than if i is heated by an open fire.

The electric method has the advantage that the heat can be applied while the bar is being forged.

The piece is always in sight, and loss of work by burning would be very rare, if not impossible.

Pieces can be heated without removal from the anvil more than a few inches.

The heat can be applied to just the part desired and no other — a great saving in power.

The loss of iron by oxidation is very slight and is given at about 2.65 per cent. when bar is heated in air, and 1.65 per cent. when heated under some protection.

It must be obvious that a quick heat will cause less oxidation than a longer one.

The temperature can be regulated to any desired degree from nothing up to melting, and held at any point as long as practical working would call for.

In tempering, bars can be brought up to a given predetermined heat by setting the regulator in a certain position for the heating of a number of pieces as long as the power remains constant.

There are no working parts about the transformer, which should last for a long time without any repairs.

The heating of a piece is even through its entire length, which is very difficult with ordinary heating processes, and would for some work be very valuable.

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[1] The price of blacksmith coal, $1.65, used in the estimate is as much lower than the market as $1.25 per ton for slack coal to be used under the boilers, so that the estimates for coal and the comparison are on the same basis.

The fifteen power tests given in the table below were taken in October last by Mr. F. H. Crane, mechanical engineer of the Emerson Power Scale Company. It will be seen that the percentage of power used in heating brass is much less than for heating iron or steel, but the time required to heat brass is longer than that required to heat iron or steel, so that the horse power necessary to heat a cubic inch of brass per minute figures about the same in the final result. This also applies in the heating of copper, and shows that the cost of heating iron, brass, copper, or steel by electricity is about the same.

Power Tests on 50 H. P. Electrical Heating Apparatus of the Electrical Forging Co., Boston, by F. H. Crane, S.B., mechanical engineer, Emerson Power Scale Co., Boston.

No. of Pieces.	Kind of Metal.	Size of Each Piece Heated to a Forging Heat.	Cubic Inches.	Time Heating. M. S.	Average H. P.	H. P. per Cubic Inch per Minute.
2	Iron.	1 x ½ in. x 4 ft. long	48	3.20	51.5	3.75
4	"	½ x ½ in. x 3 ft. long	36	2.	58.8	3.27
4	"	1 x ½ in. x 3 ft. long	72	4.	52.7	2.93
2	Steel.	1 x 1 in. x 3 ft. 1 in. long . .	74	5.	44.8	3.02
3	"	1 x 1 in. x 3 ft. long	108	8.	47.	3.48
3	Iron.	1 x ½ in. x 3 ft. long	54	3 30	52.4	3.38
3	"	1 x ½ in. x 4 ft. long	72	4.	53.1	2.95
4	"	1 x ½ in. x 4 ft. long	96	6.	54.8	3.43
4	Steel.	1 x ⅜ in. x 4 ft. long	72	4.	58.3	3.24
2	Iron.	1 x ⅜ in. x 4 ft. long	72	5.	49.9	3.44
4	"	1 x ⅜ in. x 3 ft. long	54	2.45	58.3	2.97
4	"	1 x ⅜ in. x 3 ft. long	54	2.40	57.	2.82
4	"	½ x ½ in. x 3½ ft. long . . .	42	2.30	52.4	3.09
4	"	1 x ⅜ in. x 3½ ft. long . . .	63	3.20	53.8	2.84
1	Hard Brass.	1 x 1 in. x 2 ft. 8 in. long . .	32	3.30	34.2	3.74

ON THE DISSOCIATION OF HYDROGEN IONS FROM ACID SALTS.

By ARTHUR A. NOYES, Ph.D.

Received January 27, 1893.

The chemical activity of an acid, or the readiness with which it causes and enters into chemical reactions, depends, according to the electrolytic dissociation theory, on the extent of its dissociation into ions; and the measurement of the rates at which a reaction takes place under the influence of various acids is one of the methods of determining their relative dissociation. The reaction most commonly employed for this purpose is the inversion of cane sugar, which takes place only in the presence of hydrogen ions and at a rate nearly proportional to their concentration. In an article recently published Trevor[1] has shown that this method can also be used at 100° for measuring very small degrees of dissociation, and has applied it to the determination of the number of hydrogen ions dissociated from acid salts. His results are of special interest, as they furnish the only data of the kind which we possess; for the measurement of the electrical conductivity is of no assistance in this case since so many different kinds of ions are present. In connection with some solubility experiments with the acid potassium tartrate my attention was especially directed to this article, and I desire here to offer an explanation of some of the general results arrived at by the author.

I refer in the first place to the change of the dissociation into hydrogen ions with the dilution. In the case of weak acids Ostwald and others have found the dissociation nearly proportional to the square root of the volume in which one molecular weight is dissolved,

[1] Zeitschrift für physikalische Chemie, 10, 321.

and this result is a necessary deduction from the law of chemical mass action. In the case of acid salts of weak acids, however, Trevor finds that the dissociation increases in the same proportion as the volume itself; in other words, that the quantity of hydrogen ions in the solution is independent of the dissolved quantity of the acid salt. It appears to me of some importance to show that this remarkable result, instead of being a contradiction, is a consequence of the law of mass action, and especially so, as it offers an interesting and experimentally confirmed application of that law to a rather complicated case of equilibrium.

The cause of this difference in the behavior of weak acids and their acid salts lies in the fact that, while in the case of the former the two ions are necessarily produced in equal quantities, this is by no means true in the case of acid salts, as will be evident from what follows. For there exist in the solution of an acid salt MHA seven different kinds of molecules, namely: MHA, $\overset{+}{M}$, $\overset{-}{HA}$, $\overset{+}{H}$, $\overset{=}{A}$, H_2A, and M_2A. In dilute solution — the strongest investigated by Trevor was $\frac{1}{32}$ normal — the quantities of the undissociated salts MHA and M_2A, are very small and can be neglected. The quantity of the metal ion M does not come into consideration. Between the other quantities, according to the law of mass action, the following relations exist, where the symbols stand for the molecular quantities in the unit of volume of the substances or ions represented by them, and k and c are dissociation constants:

$$c \times \overline{HA} = H \times A \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$
$$k \times \overline{H_2A} = H \times \overline{HA} \quad . \quad . \quad . \quad . \quad (2)$$

Furthermore, as the negative ions A are produced according to the chemical reaction: $2HA = H_2A + A$, as well as by the direct dissociation $HA = H + A$, we have the equation:

$$A = H + \overline{H_2A} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and finally calling m the total number of molecules in the solution, or the concentration of the salt:

$$m = \overline{HA} + \overline{H_2A} + A \quad . \quad . \quad . \quad . \quad (4)$$

where, as above said, the quantities $\overline{MHA}$ and $\overline{M_2A}$ are neglected.

From (1) and combination of (3) and (4) follows:

$$\overline{HA} = \frac{H \times A}{c} = m + H - 2A \quad \text{or}$$

$$H \times A = cm + cH - 2cA \quad . \quad . \quad . \quad . \quad . \quad (5)$$

From (1) and from combination of (2) and (3) follows:

$$\overline{HA} = \frac{H \times A}{c} = \frac{kA - kH}{H} \quad \text{or}$$

$$A = \frac{ckH}{ck - H^2} . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

If this value is substituted in equation (5) and the expression reduced we get

$$ck = \frac{(k + m + H)\, H^2}{m - H} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

According to Trevor's experiments, however, the ratio of the quantity of hydrogen ions to the total quantity of the salt m is very small — in almost all cases less than one per cent. Formula (7) can therefore be written without sensible error:

$$ck = \frac{(k + m)\, H^2}{m} . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

or, putting $\frac{H}{m} = d$, the dissociation,

$$ck = (k + m)\, md^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

The constant k in these equations is the affinity constant of the free acid, and is known from the measurements of the electrical conductivity.

It is now clear, when the acid is so weak that its dissociation constant k can be neglected in comparison with the concentration m, that formulas (8) and (9) reduce to:

$$H = md = \sqrt{kc} = \text{a constant.}$$

That is, the law of mass action requires in the case of an acid salt of a sufficiently weak acid that the quantity of hydrogen ions be independent of the concentration, or, in other words, that the dissociation increase proportionately to the dilution.

Let us consider now Trevor's results. The acid salts whose dissociation he found to increase proportionately to the dilution are given in the following table, together with their percentage dissociation:

Acid sodium salt of	$m = 0.0312$	$m = 0.0156$	$m = 0.0078$	$m = 0.0039$	Constant of the acids.
Suberic acid	0.03	0.05	0.10	0.20	0.0030
Adipic acid	0.04	0.07	....	....	0.0037
Glutaric acid	0.04	0.07	0.13	....	0.0047
Succinic acid	0.05	0.08	0.14	0.33	0.0067
Pyrotartaric acid	0.04	0.08	0.15	....	0.0086

In the last column the affinity constants (k) of the free acids are given as determined by Ostwald. These values are a hundred times greater than the true dissociation constants. These latter are therefore entirely negligible even in comparison with the smallest value of the concentration m; for example, 0.000067 in comparison with 0.0039; the proportionality between dissociation and dilution was therefore to be expected.

In the case of the salts of the stronger acids Trevor found that the dissociation increases more slowly than the dilution. This increase should take place theoretically according to formula (8). An exact agreement of the observed and calculated values is, however, not to be expected, for both Ostwald[1] and Trevor[2] have established the fact that the ratio of the velocity of inversion to the quantity of hydrogen ions decreases with increasing dilution. I give some examples to show that an approximate agreement nevertheless exists. This, in the case of oxalic acid — where, moreover, the dissociation is large — is quite satisfactory; and in all cases the small deviations lie in the expected direction. The calculated values of the dissociation in the following table are obtained by calculating by means of formula (8) (formula (7) in case of oxalic acid) from the values inclosed in parentheses those for the other concentrations.

[1] Journal für praktische Chemie, (2) 31, 312.

[2] Zeitschrift für physikalische Chemie, 10, 339.

Acid sodium salt of		Value of the Dissociation for			
		$v = 32$	$v = 64$	$v = 128$	$v = 256$
Ortho-phthalic .	found . . .	0.19	0.34	0.62	....
	calc.	0.17	(0.34)	0.66	....
Meta-phthalic . .	found . . .	....	....	0.69	1.23
	calc.	....	....	0.63	(1.23)
Citraconic . . .	found . . .	0.12	0.21	0.33	0.59
	calc.	0.09	0.18	(0.33)	0.58
Oxalic	found . . .	....	2.92	4.37	6.13
	calc.	....	3.00	(4.37)	6.24

In regard to a second point considered in Trevor's article I would like to say a few words. In comparing the dissociation of the acid salt with that of the corresponding acid only the quantity of the hydrogen ions is considered. Now, while in the case of an *acid* the two ions are necessarily produced in equal quantities, this is not true in the case of an acid *salt*, but the acid ion $\bar{\bar{A}}$ is always present in greater quantity, and in so much greater quantity the weaker the acid. (Compare formula (3).) It is evident from formula (8) that the quantity of hydrogen ions depends not only on the dissociation constant c of the acid ion $\overline{HA}$, but also on the constant k of the acid itself. I have therefore calculated from Trevor's experiments the values of the true dissociation constant c for the dilution $v = 64$, and these values are given in the following tables:

HOMOLOGOUS ACIDS.

	$k \cdot 10^6$	$c \cdot 10^6$	$100\,d$.
Suberic	30	2.1	0.05
Adipic	37	3.2	0.07
Glutaric	48	2.5	0.07
Succinic	67	2.3	0.08
Pyrotartaric	86	1.8	0.08
Malonic	1,580	0.75	0.21
Oxalic	100,000	16.	2.92

If only the relative quantities of hydrogen ions (given in the last column) are considered we should conclude with Trevor that the dissociation of the free acids and that of their acid salts varies in the same direction. This behavior would be, however, inconsistent with the hypothesis of Ostwald[1] on the cause of the weakness of the acid salts, according to which the negative charge of the first carboxyl group prevents the dissociation of the hydrogen from the second; for this should take place with greater difficulty the nearer the two carboxyls are to each other. By comparing the dissociation *constants* c, however, this requirement of the hypothesis is seen to be in general fulfilled; for while k on account of the greater proximity of the carboxyls increases, c regularly decreases for the same reason. Only oxalic acid, the extreme member of the series, forms an important exception.

ISOMERIC ACIDS.

	$k \cdot 10^6$	$c \cdot 10^6$	$100\,d$.
o-phthalic	1,210.	2.2	0.62
m-phthalic	290.	10.	0.69
Maleic	11,700.	0.55	0.39
Fumaric	930.	20.	0.85
Citraconic	3,400.	0.39	0.21
Mesaconic	790.	6.3	0.44

In the case of these isomeric acids we find again the same relations between the dissociation constants of the acids and those of their acid salts; only in this case the differences in the latter are so great that the relative dissociation of the salts is evident from the quantity of hydrogen ions alone.

MALONIC ACID DERIVATIVES.

	$k \cdot 10^6$	$c \cdot 10^6$	$100\,d$.
Malonic	1,580.	0.75	0.21
Ethylmalonic	1,270.	0.35	0.13
Dimethylmalonic	770.	0.27	0.09

[1] Zeitschrift für physikalische Chemie, 9, 558.

The conditions here are exactly the reverse of those illustrated by the previous tables — a greater dissociation of the acid corresponds to a greater dissociation of the salt. Exactly the same thing is found on comparing maleic and citraconic acids, or also fumaric and mesaconic acids. (See the previous table.) All these cases are, however, different in principle from those before considered; for the greater dissociation of the one acid is here caused not by a nearer position of the carboxyls to one another, but by the introduction of more negative groups; and this latter increases, of course, also the dissociation of the second hydrogen ion.

The two following principles can then be stated as corollaries from Ostwald's hypothesis.

1. The dissociation constant of a dibasic acid is greater, and that of its acid salt is smaller, the nearer the carboxyl groups are to each other.

2. The introduction of new groups into a dibasic acid influences the dissociation constants of the acid and its acid salt in the same direction.

These principles are confirmed, as we have seen, by Trevor's experiments.

THE STUDY OF BACTERIA IN DRINKING WATER.

By GEORGE W. FULLER, S.B., Bacteriologist in Charge, Lawrence Experiment Station, State Board of Health of Massachusetts.

Received February 8, 1893.

The bacteriology of water[1] has advanced with an increased impetus during the past few years, since it has been established that the specific germs of several diseases are able to live for some time in potable water, and that the death rate of cities and towns in regard to these diseases is, to a large extent, dependent upon the quality of the water supply.

As is well known, the number of bacteria in water and in other materials is determined by the use of the gelatine-peptone plate method devised, in 1881, by Koch. A known amount of water is mixed with a tube of properly prepared melted gelatine and poured into a glass dish. The gelatine, as well as all apparatus with which the water comes in contact, must have been previously sterilized. The gelatine quickly solidifies and holds in isolation each individual bacterium, which multiplies rapidly in this rich food material, and after two to three days at a temperature of 20° C. forms a "colony." These colonies are readily counted by the aid of a hand lens.

From the outset it was more or less recognized that this method was not a perfect one, and that some species of bacteria are not able to develop in this culture medium. The bacillus of tuberculosis fails to grow in nutrient gelatine, and the nitrifying organisms, which play such an important rôle in the economy of nature by converting decaying organic matter to harmless mineral matter, entirely escaped identification for many years, on account of their inability to develop in this medium. A large majority of these minute plants require an alkaline food material, and, furthermore, it has been found that different

[1] For the literature and a summary of our present knowledge upon this subject see Report of Profs. P. F. Frankland and Marshall Ward, Proceedings of the Royal Society, Vol. LI, No. 310.

species of bacteria in water require different degrees of alkalinity. Experienced bacteriologists[1] agree that, in order to make bacterial water analyses of value for comparison, the culture medium shall be of a uniform degree of alkalinity (the optimum degree for maximum development), and that the conditions in regard to the composition of the nutrient gelatine, the temperature, and period of cultivation shall be as nearly parallel as possible. The following table shows the variableness of the number of bacteria in the same sample from the use of gelatine of different degrees of alkalinity, and with all other conditions the same. Number A was acid; the others were alkaline and in regularly increasing amounts. The numbers express the bacteria in a cubic centimeter.

	A.	B.	C.	D.	E.
Lawrence City water . . .	3	18	160	240	606
Lawrence sewage	146,000	517,000	770,000	1,526,000	910,000

In addition to the many improvements which have been made in the general methods and manipulation, special methods and media have been devised for the study of some of the most important species of bacteria.

After the introduction of this quantitative method numerous determinations were made of the bacterial contents of water. It was found that many surface waters were very rich in bacterial life, while spring and deep well waters were, as a rule, comparatively free. In a general way it was learned that the number of bacteria in a water was proportional to the amount of organic matter present which could serve them as a food material. Enthusiastic bacteriologists were not slow to set up arbitrary standards for the purity of water, based on the results of their determinations, and to express the opinion[2] "that chemical analyses were retained and practiced only on the ground of thoughtless tradition."

The promoters of this doctrine met a severe setback in 1885, when it was discovered[3] that bacteria are able to live upon an ex-

[1] Reinsch, Centralblatt für Bakteriologie, 1891, 10, 415. Annual Report of Massachusetts State Board of Health for 1891, p. 620. Dahmen, Chemiker-Zeitung, 1892, No. 49.

[2] Fraenkel, Grundriss der Bakterienkunde, Dritte Auflage, S. 487.

[3] Meade Bolton, Zeitschrift für Hygiene, 1, 76.

tremely small amount of food material. It was even claimed at that time that certain species of bacteria are able to multiply in distilled water. The manipulation in these experiments was not above criticism, but in the light of our present knowledge it is definitely known that some kinds of bacteria grow on very small amounts of organic matter. It has been found that several species of bacteria present in the water of the Merrimack River are capable of growth in a solution containing one part of peptone in one hundred million parts of redistilled filtered water. From this it will be readily understood that some bacteria multiply to a considerable extent in water containing the merest trace of harmless organic matter of a vegetable origin; and that from this time forth cautious sanitarians have regarded the bacteriological analysis of water as an important supplement to, but by no means a substitute for, chemical analysis.

Modern hygiene demands that a drinking water shall be free from all disease-producing germs. The old conventional standard that a good water ought not to contain more than two hundred bacteria per cubic centimeter is evidently untrustworthy, because, as has been many times pointed out, it is perfectly possible that a water might contain five thousand bacteria of a harmless nature, and not be dangerous for drinking, while another water might have ten bacteria in a cubic centimeter among which were germs of typhoid fever or of Asiatic cholera. The greatest service which the bacterial analyst of water can render hygiene is to be able to quickly and accurately determine whether a given water contains any pathogenic bacteria. Unfortunately, with the methods at our present command, this problem is extremely difficult, and requires several days and possibly weeks of careful work before it can be solved, and then, in many cases, the results are associated with more or less doubt. Furthermore, in many cases the water is not submitted to the bacteriologist until the epidemic is practically over, and the course of the disease is therefore very little, and possibly not at all, affected by the bacteriological investigations. It is accordingly necessary for the health of the consumers to condemn all drinking water which contains an appreciable amount of organic matter of an animal origin which is usually associated to a certain extent with disease germs. The fitness of a water for drinking purposes should be determined by a careful inspection of its source in addition to the bacterial and chemical analyses.

In selecting a public water supply many cities and towns are

obliged to choose a water which is not above suspicion as a carrier of disease germs. The question then arises, How can such a water be purified? In many cases this can best be done by means of filtration through sand. This method is successfully used by many of the large European cities, and its day in America is just dawning. In determining the efficiency of filtration and in obtaining useful data for the construction and manipulation of filters bacteriology plays an important part. In no other field are the bacterial methods so well adapted to the needs of the problem. Here the possible variations in bacterial results arising from certain defects in the method are offset when, under parallel conditions, the number of bacteria in the water are determined before and after passage through the filter, and a true idea of the degree of bacterial purification is obtained. The services rendered by bacteriology to hygiene in this direction are of a most practicable as well as highly important nature.

Another fruitful field of bacterial investigation is the determination of the vitality of pathogenic bacteria in drinking water. It is claimed, for instance, that the diphtheria bacillus[1] does not live in water, while the bacilli of typhoid fever and of Asiatic cholera live in diminished numbers for several weeks and possibly months. The germ of typhoid fever has been found to live for twenty-four days[2] in the water of the Merrimack River at Lawrence. To study this problem under conditions parallel to those which occur in nature is extremely difficult. Fortunately for the public health disease germs very rarely occur in water in numbers sufficiently great to enable them to be readily recognized among the harmless species of water bacteria. It thus becomes necessary to inoculate the water with the germs to be studied; and with them, in many cases, is introduced considerable organic matter which serves them as a food material. The nature of the associated species of water bacteria, the food material, temperature, aëration, relation to light, etc., differ much in different experiments, and doubtless go far to explain the wide divergences in the results of several investigators.

The following method of procedure has been found to serve well for the inoculation of water: The bacteria are grown for four days at 20° C., or for two days at 37.5° C., in a solution containing one tenth per cent. peptone and two tenths per cent. glucose in city water

[1] Thorne. Diphtheria: Its Natural History and Prevention, p. 101.

[2] These and following data appeared in the State Board of Health Report for 1891.

which contains phosphates and other desirable inorganic compounds. The water is infected by introducing this solution in the proportion of one part in ten thousand. The amount of organic matter added to the water with the bacteria has been found to be practically within the limits of variation of the organic matter of the water of the Merrimack River.

After a water is properly inoculated with disease germs it is no easy task, in many cases, to differentiate the bacteria under consideration from those regularly present in the water. It is first necessary to obtain a good general knowledge of the specific characteristics of the water species, and from these data devise means of differentiation. The prominent part in the development of bacteriology which has been taken by harmless water bacteria is remarkable. Bacteriology was first applied to the study of pathogenic bacteria, and methods for their differentiation were found. After our knowledge was extended to the bacteria of water it was learned that some of them fulfilled all the laboratory requirements for the identification of disease germs. Thus in the case of the bacillus of typhoid fever it was thought for several years that the characteristic invisible growth upon sterilized potato was sufficient to differentiate it from all other species. It is now known that at least five species of water bacteria satisfy this and other laboratory conditions, and new methods of diagnosis have been accordingly devised. The comparative study of the different kinds of bacteria in water, indeed, offers a very fruitful field of investigation to well-trained bacteriologists.

In making a thorough hygienic study of the water of the Merrimack River at Lawrence, one of the first steps was to become familiar with the prevailing species of bacteria. Side by side with this study the problem of bacterial purification by sedimentation and passage through iron pipes was also investigated. Several times each month bacterial samples of water were taken from different parts of the Lawrence Water Works as follows:

1. From the force main at the pumping station as the water comes direct from the river.

2. After the water had passed through the reservoir, which has a capacity of about two weeks' consumption.

3. From a tap at the City Hall, which is about one and a half miles distant from the reservoir.

4. From a tap at the experiment station, which is about two and a half miles distant from the reservoir.

TABLE OF MONTHLY AVERAGES OF THE NUMBER OF BACTERIA IN A CUBIC CENTIMETER OF WATER FROM DIFFERENT PARTS OF THE LAWRENCE WATER WORKS.

1891.	Pumping Station.	Reservoir.	City Hall Tap.	Experiment Station Tap.
January	2,872	713	347	72
February	1,387	224	92	34
March	890	222	98	33
April	770	390	190	62
May	4,030	242	68	49
June	3,690	192	50	95
July	5,030	507	219	188
August	1,920	317	521	181
September	12,150	262	166	144
October	12,550	888	975	356
November	3,576	408	300	122
December	11,440	2,384	1,215	401
Averages	5,025	562	353	145

From this table it will be seen that the number of bacteria in the water drawn from service pipes is much smaller than in the river water, and that this decrease takes place chiefly in the reservoir, due largely to sedimentation, lack of suitable food material, and influence of light. The average amount of bacterial purification for the year 1891 of water at different places was as follows:

TABLE SHOWING THE PERCENTAGE OF BACTERIA IN THE WATER OF THE MERRIMACK RIVER WHICH WERE REMOVED BY PASSAGE THROUGH THE RESERVOIR AND PIPES OF THE LAWRENCE WATER WORKS.

Water after leaving the reservoir	89	per cent.	of bacteria removed
Water from tap at City Hall	93	"	" "
Water from tap at experiment station	97	"	" "

This table does not give a true idea of the relative purity of the service water, because some of the river water passes through the

reservoir before purification takes place. This amount varies, among other things, with the temperature of the river water compared with that of the water which it meets in the reservoir. If the entire supply remained in the reservoir for two weeks the purification would doubtless be greater and the danger in using it for a drinking water diminished to a certain extent. It is not advisable, however, to depend upon purification by storage alone now that it has been determined that a practically complete bacterial purification of the water can be effected by filtration through sand.

In order to study more closely the seasonal effects upon the bacteria and the life history and specific characteristics of the different species, the number present of each of the prevailing species of bacteria in the different samples was determined. The quantitative determination of the prevailing species of bacteria in water is not known to have been made elsewhere. The method practiced is as follows:

All of the colonies on a gelatine plate are carefully examined and an estimation made of the number of each kind presenting marked characteristics. This places together in groups those kinds superficially resembling one another. One or more colonies of each group are "fished," and ten or more colonies possessing no marked characteristics on the gelatine (including many non-liquefying colonies lying beneath the surface) are taken at random; and in case of less than ten such colonies all are taken. To facilitate the separations dilutions are made of those waters containing high numbers of bacteria. A pure culture is obtained from each colony that is fished, and their identity established by the tests regularly employed by bacteriologists. After this is done the number present of those species possessing marked characteristics on the gelatine plate is easily calculated, and of the remainder each species is given its aliquot portion.

From a classification of the data upon the specific characteristics of the different water bacteria, a scheme of procedure can be developed which will enable pathogenic bacteria to be most readily and accurately differentiated. The life histories of the prevailing species of bacteria in water are in themselves of interest and importance, and are of still greater value for comparison. When laboratory experiments upon the life history of a disease germ in water are made side by side with those upon a prevailing species of bacteria in the given water, and the life history of which, under conditions actually found in nature, is already known, an excellent check is obtained upon the experimental conditions.

This investigation showed that *B. coli communis*, the leading species of bacteria in human fæces, formed thirty-nine per cent. during the months of November and December, 1891, of the bacteria in the water of the Merrimack River at Lawrence. Its life history in the water, after passing through the reservoir and service pipes, indicated it to be a very persistent organism. It has accordingly been used to advantage for laboratory experiments. In virtue of its origin, moreover, its presence in a water is a ready indication of contamination of animal nature and of danger from its use as a drinking water.

MEASUREMENT OF STEAM BY THE FLOW THROUGH AN ORIFICE.

By E. F. MILLER, S.B., and C. A. READ, S.B.

Received February 9, 1893.

In the apparatus shown in Figure 1, page 359, FF are two pieces of 2″ pipe each about 16″ long, having a 2″ pipe flange on one end and a reducing coupling on the other. There is a gauge B and a drip D on the entrance side, and a gauge C and thermometer cup E on the exit side. At A between the flanges there is a brass plate with an orifice through which the steam to be measured flows. If the pressure at C is much lower than that at B the steam on the exit side of the orifice is apt to be superheated, the number of degrees of superheat being the difference between the thermometer reading at E and the temperature of steam corresponding to the pressure C. Knowing this and the pressure C we can calculate the British Thermal Units per pound of steam supplied to the machine tested. This machine when made of 2″ pipe is suitable for amounts up to 250 pounds per hour with 110 pounds gauge pressure at B. It is not advisable to have the orifice in the plate A over $\frac{1}{2}$″ diameter if FF is of 2″ pipe; but if FF is made larger in diameter, larger orifices can be used. By having a number of orifice plates A with different sized holes the weight of steam delivered can be varied, as can also the back pressure C. The orifice plates are brass disks 5″ diameter and $\frac{1}{4}$″ thick, such as are kept in stock at hardware stores. The orifices were bored out in a speed lathe, no pains being taken to get any special diameter. The diameters were obtained by fitting arbors to the holes and then calipering the arbors with a micrometer caliper reading to one ten-thousandth of an inch. The entrance side of the orifice is rounded with a smooth curve tangent to the plate and to the straight part of the orifice.

Two pieces of apparatus like that described above, also one of 3″ pipe, were made and tested in the Engineering Laboratories. The tests, many of which formed part of the fourth year laboratory work,

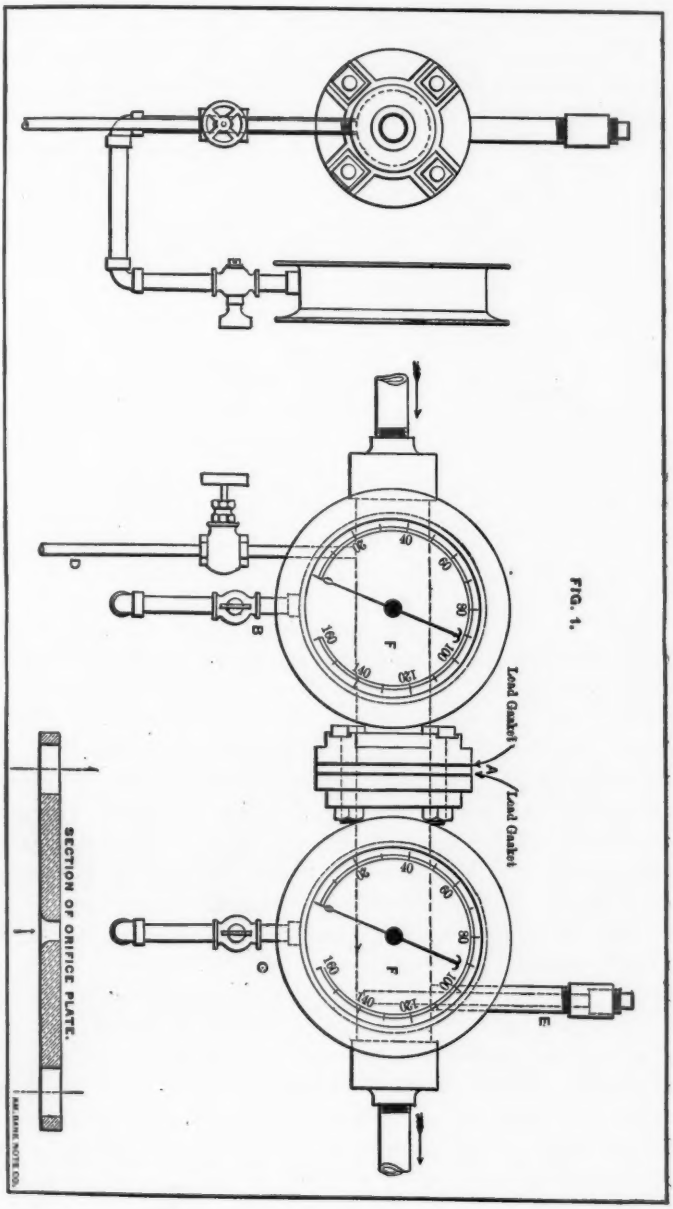

FIG. 1.

were carefully made. Steam gauges B and C were tested by comparison with an open mercury column. The steam after passing through the apparatus was condensed in a Wheeler condenser, which was repeatedly tested for leaks and found to be perfectly tight. The calculated amount was obtained by applying Napier's formulæ given below:

$$P_1 = \text{or} > \tfrac{5}{8} P_a \qquad G = F \frac{P_1}{70}$$

$$P_1 < \tfrac{5}{8} P_a \qquad G = F \frac{P_a}{42} \left\{ \frac{3(P_1 - P_a)}{2 P_a} \right\}^{\frac{1}{2}}$$

P_1 is the absolute pressure on entrance side.
P_a is the absolute pressure on exit side.
F is the area of the orifice in square inches.
G is the weight in pounds per second flowing through.

In Table I tests 1 to 15 inclusive were made with the 2″ apparatus. The orifice used was .2285″ diameter. These tests are arranged with reference to the ratio of the absolute pressures — Column 6. The coefficient given in Column 9 is the number by which the calculated amount, given in Column 8, must be multiplied to get the correct amount determined by experiment — Column 7. This coefficient gradually increases as the difference of pressures decreases. With a ratio of pressures equal to .9, the disagreement of Napier's formulæ appears to be about 5 per cent., while with a ratio equal to .5, the disagreement is about 2 per cent.

Tests 16 to 26 inclusive were on the 3″ apparatus with an orifice .4136″ diameter. In these the coefficients increase as the difference of pressures decreases, but in every case the coefficients are larger than for the same ratio of pressures in tests 1 to 16. Tests 27 to 32 are a few scattering tests with different boiler pressures. After having determined for an orifice coefficients for different ratios of pressures, the boiler pressure being very nearly constant, this apparatus can be used with a fair degree of accuracy.

It is a very convenient apparatus for finding the weight of steam used by inspirators, ejectors, pulsometers, and other apparatus of the same sort, where steam is in contact and mingles with the water pumped, rendering the use of a condenser impracticable. The cost of the apparatus, not including the gauges, did not exceed three dollars.

Besides these tests a number were made on a similar apparatus, a description of which, together with some results, can be found in

Volume XI of Transactions of the American Society of Mechanical Engineers. In this apparatus the chambers FF are about 5″ diameter and 24″ long. An orifice .25″ diameter and $2\frac{1}{2}$″ long was used (Figure 2). By means of a small hole entering, at right angles, the straight

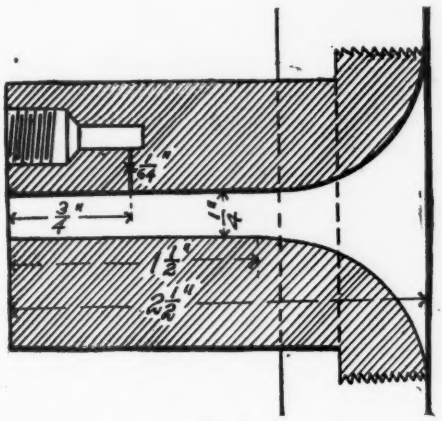

Fig. 2.

part of the orifice, and a connecting pipe running through a stuffing box on the outside, the pressure in the orifice was measured. As the chamber is large compared with the orifice it is assumed that the velocity in the chamber is zero.

For an adiabatic flow through the orifice we have the formulæ (see "Thermodynamics of Steam Engine." — *Peabody*):

$$A\frac{w^2}{2g} = x_1 r_1 + q_1 - x_2 r_2 - q_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\frac{x_1 r_1}{T_1} + \Theta_1 = \frac{x_2 r_2}{T_2} + \Theta_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$G = \frac{f\,w}{x_2 u_2 + .016} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

A = heat equivalent of one foot pound.
w = velocity in feet per second of steam in orifice.
$2g = 64.32$.
x_1 = quality of entering steam as determined by a calorimeter test .989 throughout all these tests.
r_1 = latent heat at absolute entrance pressure.
T_1 = absolute temperature of steam at entrance.
Θ_1 = entropy of liquid at entrance pressure.
q_1 = heat of liquid at entrance pressure.
f = area of orifice in square feet.

x_2, r_2, T_2, and Θ_2 all refer to the above at absolute orifice pressure.

$u_2 = S_2 - .016$ = volume of a pound of steam at orifice pressure, minus volume of a pound of water.

G = weight in pounds per second flowing through.

x_1 being known, x_2 is obtained from equation (2), and this value substituted in (1) enables us to solve for w. In equation (3) the numerator is the number of cubic feet per second, and the denominator is the number of cubic feet in one pound of the mixture of steam and water in the orifice.

In Table II the calculated weight was worked by the thermodynamic formulæ and also by Napier's formulæ. Column 8 gives the coefficients for Napier's formulæ, and Column 10 those for the thermodynamic equation. These coefficients are nearly alike and all are less than one, while in the first table the coefficients were all more than one. This difference is probably due to the greater friction in the longer orifice. The orifices soon wear rough, and must be trued and polished frequently.

TABLE NO. I.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
No. of Test.	Boiler Pressure by Gauge.	Back Pressure by Gauge.	Boiler Pressure Absolute.	Back Pressure Absolute.	Ratio of Absolute Pressures.	Steam by Experiment, lbs.	Steam by Equation, lbs.	Coefficient.	Diameter of Orifice, ins.
1	108.0	41.2	122.8	56.0	.500	264	259	1.019	.2285
2	108.3	51.2	123.1	66.0	.536	265	259	1.023	"
3	107.5	55.5	122.7	70.3	.573	265	259	1.025	"
4	107.6	60.0	122.4	75.8	.619	262	256	1.024	"
5	108.5	58.7	123.3	73.5	.596	266	260	1.025	"
6	108.3	59.6	123.1	74.7	.607	266	259	1.025	"
7	106.6	61.9	121.5	76.8	.632	261	252	1.037	"
8	107.8	64.1	122.7	79.2	.645	262	252	1.040	"
9	108.0	68.7	122.9	83.6	.680	257	247	1.040	"
10	108.4	70.8	123.1	85.5	.695	251	244	1.027	"
11	108.4	81.5	123.3	96.4	.772	227	219	1.036	"
12	108.6	86.4	123.5	101.3	.820	215	204	1.054	"
13	110.2	92.8	125.2	107.8	.861	194	186	1.043	"
14	109.4	95.5	124.3	110.4	.888	178	169	1.058	"
15	110.5	100.9	125.5	115.9	.924	151	143	1.056	"
16	92.0	7.2	107.0	22.0	.206	770	739	1.055	.4136
17	96.3	8.3	111.2	23.2	.209	796	768	1.035	"
18	45.5	2.9	60.4	17.8	.294	441	417	1.057	"
19	97.1	30.6	112.0	45.5	.407	808	774	1.044	"
20	95.5	40.2	110.4	58.1	.526	795	763	1.042	"
21	95.7	49.8	110.4	64.5	.584	798	763	1.046	"
22	95.8	54.9	110.6	69.7	.630	793	754	1.052	"
23	93.8	60.2	108.6	75.0	.691	762	708	1.076	"
24	93.2	65.0	108.2	80.0	.749	734	700	1.094	"
25	97.7	77.0	112.7	92.0	.816	692	616	1.124	"
26	106.2	97.2	121.0	112.0	.926	510	448	1.138	"
27	18.6	3.9	33.4	18.7	.560	246	231	1.066	"
28	8.2	1.6	23.1	16.5	.714	154	147	1.046	"
29	6.8	1.1	21.5	15.8	.735	142	134	1.063	"
30	53.2	38.0	68.0	52.8	.776	447	400	1.117	"
31	20.5	14.5	35.3	29.3	.830	212	187	1.131	"
32	17.4	13.5	32.1	28.2	.879	165	148	1.116	"

TABLE NO. II.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
No. of Test.	Boiler Pressure Absolute.	Back Pressure Absolute.	Orifice Pressure Absolute.	Ratio of Absolute Back to Absolute Boiler Pressure.	Steam by Experiment.	Steam by Napier's Rule.	Coefficient.	Steam by Thermodynamic Eq.	Coefficient.
1	122.1	17.7	76.5	.145	302	308	.981	308	.981
2	122.8	18.2	77.8	.148	306	310	.987	308	.993
3	117.7	18.0	74.4	.153	291	297	.979	295	.984
4	123.5	47.7	78.1	.386	306	312	.981	311	.983
5	122.5	30.4	77.7	.248	305	309	.986	308	.992
6	123.2	34.3	78.2	.278	305	311	.981	308	.990
7	122.6	36.0	78.1	.294	304	310	.982	306	.993
8	126.1	102.2	103.5	.810	252	255	.989	262	.979
9	123.3	111.5	112.9	.904	186	187	.995	190	.980
10	123.6	112.7	113.9	.912	178	181	.986	185	.965

EXPERIMENTS WITH THE PHONOGRAPH RELATING TO THE VOWEL THEORY OF HELMHOLTZ.[1]

By CHARLES R. CROSS and GEORGE V. WENDELL.

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The value of the phonograph as an aid in the study of the theory of vowel tones was recognized almost immediately upon the invention of that instrument, and it was employed for this purpose as early as 1878 by Messrs. Jenkin and Ewing,[2] and also by Dr. C. J. Blake in connection with one of the present writers. The experiments of the last mentioned observers were designed to aid in the solution of the question whether it is a fact, as assumed by Helmholtz, that each vowel possesses a distinctive character due to the presence of a particular tone or tones, which are the resonance notes of the mouth cavity when shaped for the utterance of the corresponding vowel. The method employed and the results obtained were described in a letter to *Nature* (Vol. XVIII, p. 93), so that a brief reference to them will suffice.

The plan followed was to speak a vowel into the mouthpiece of the phonograph when the cylinder was revolved at a certain rate, and then to reproduce the tone with a varying rate of revolution, both faster and slower than that used when the record was impressed upon the cylinder. Any particular resonance note, if present, would then have its pitch raised or lowered, and presumably the vowel sound would be correspondingly altered.

This was found to be the case, the vowel apparently changing with change of speed of the cylinder. For example, the vowel *ō* changed to *e* on increasing the speed to a rate considerably above that at which the former vowel was impressed upon the recording cylinder, and fell to *å* when the speed of the cylinder was carried considerably below

[1] Read at a meeting of the American Academy of Arts and Sciences, May 24, 1892.

[2] See Nature, Vol. XVII, p. 384; Trans. Roy. Soc. Edinburgh, Vol. XXVIII, p. 745.

that at which the record was made.[1] Various other results of the same character were secured.

The accuracy of these results was questioned, but they were shortly afterwards confirmed by A. G. Bell and F. Blake,[2] and others. The only form of phonograph in existence at that time, however, remarkable as it then seemed to be, was extremely crude and imperfect, the tin-foil employed as a medium for receiving the record not being well fitted to receive and retain the delicate impressions of the sounds of the human voice. Upon the commercial introduction of the modern phonograph of Edison, in which a cylinder of wax replaces the tin-foil, and which leaves little to be desired so far as clearness of articulation is concerned, it appeared to be desirable to repeat the early investigations just referred to with the improved instrument. After our work was well advanced, our attention was called to investigations in the same direction by Hermann.[3] But his very valuable researches on vowel tones, and their study by the aid of the phonograph, have mostly employed methods other than the one under consideration, and only some general results by this particular method seem to have been published by him. These are in accordance with the observations described in the letter to *Nature* already mentioned.

The method followed in the present series of experiments is identical with that used in the earlier studies referred to. As the cylinder of the modern phonograph is rotated by an electro-moter furnished with a good speed-governor, it was easy to vary the speed within moderately wide limits, and to keep it at a tolerably definite and known rate, which was done in most of our experiments. In some of these, however, only general results were sought for, and no attempt was made to measure the speed.

We proceed to give a detailed description of a few of our more general preliminary experiments, which is followed by a statement in tabular form of the later and more precise observations. In the former, we have noted only those sounds which seemed most prominent in the different series.

(1) The vowel *ö* was spoken into the speaking-tube of the phonograph when the cylinder was rotated at the lowest speed at which it

[1] In this paper the sounds of the different vowels are denoted by the conventional signs employed in the Century Dictionary. Certain other signs used are explained later.

[2] See American Journal of Otology, Vol. I, p. 163.

[3] Cent. f. Physiologie, 1890, Vol. IV, p. 242; Pflüger's Archiv, 1890, Vol. LXXIV, p. 42.

was possible to drive it with the governor used — about one half revolution per second. The vowel was then reproduced with a gradually increasing speed of the cylinder up to the highest possible speed — about three and one half revolutions per second. The experiment was repeated several times, and with different observers. The sounds heard as reproduced were

ö ō ou ü a.

(2) The vowel *ö* was spoken into the mouthpiece at a speed of about one revolution per second. On reproducing it at lower rates down to about one half revolution per second, the vowel sound was still heard as *ö*, but becoming more and more guttural, until at the lowest speed it sounded like a deep gurgle.

(3) The vowel *ō* spoken with a moderately low speed of the cylinder, and reproduced with gradually increased speeds from the lowest possible to the highest, gave the following sounds:

ö ō ọ̄ ou ä a.

(4) The vowel *ō* was spoken into the instrument at the highest attainable speed, and repeated a number of times, the speed of the cylinder meanwhile being lowered gradually, so that the vowel in question was impressed upon the cylinder at a variety of speeds, from the highest to the lowest. It was then reproduced with gradually increasing speed of the cylinder, beginning with the lowest possible. This procedure was well adapted to give a large number of vowel sounds in succession. The reproduced vowels noted were

ö ō ọ̄ ou ä a i.

(5) The vowel *ō* spoken at the lowest possible rate was reproduced at gradually increasing speeds. The sounds heard were

ō ä a e i.

(6) The vowel *ō* spoken at a rate of about one revolution per second was reproduced at a lower speed as *ö*, and at the lowest attainable speed as a very deep guttural *ö*.

(7) The vowel *ē* spoken with a cylinder speed of about one revolution per second, and reproduced at speeds varying from the lowest to the highest attainable, gave the following sounds:

ü ē ẹ̄ i.

The last mentioned sound was given out only at the extreme upper limit of speed.

(8) The vowel $\bar{e}$ spoken with a speed of about two revolutions per second was reproduced at a lower speed as $\ddot{u}$, but at all attainable higher speeds still retained its vowel character as $\bar{e}$.

The following tables contain the results of later experiments in which the speed of revolution was measured. Table I contains results reached when a single vowel was sounded and reproduced at various speeds. The first column contains the serial number of the experiment; the second, the name of the vowel; the third, the rate of revolution of the cylinder of the phonograph when the vowel was spoken into the mouthpiece and its record impressed upon the wax; and the fourth, the vowel sounds observed when the spoken sound was reproduced at various speeds, R_1. The speed is denoted in revolutions per second.

TABLE I.

No.	Vowel Spoken.	R	Vowels Reproduced.					
1	$\bar{o}$	1	R_1	$\frac{1}{2}$	1	2	3	
			Vowel reproduced	$\ddot{o}$	$\bar{o}$	*ou*	*ou*♯	(almost *ä*♯).
2	$\bar{o}$	1	R_1	$\frac{1}{2}$	1	2	3	
			Vowel reproduced	$\ddot{o}$	$\bar{o}$	*ou*	*ou*♯	(less sharp than in 1).
3	$\bar{o}$	2	R_1	1	2	3	$3\frac{1}{2}$	
			Vowel reproduced	$\ddot{o}$	$\bar{o}$	$\bar{o}$	*ou*	
4	$\ddot{a}$	1	R_1	$\frac{1}{2}$	1	3		
			Vowel reproduced	δ	$\ddot{a}$	*a*		
5	$\ddot{a}$	3	R_1	3	2	1	$\frac{1}{2}$	
			Vowel reproduced	$\ddot{a}$	δ	$\bar{o}$	$\ddot{o}$	
6	$\ddot{a}$	2	R_1	$\frac{1}{2}$	1	2	3	
			Vowel reproduced	$\ddot{o}$	δ	$\ddot{a}$	*a*	
7	$\bar{a}$	$\frac{1}{2}$	R_1	$\frac{1}{2}$	1	2	$2\frac{1}{2}$	3
			Vowel reproduced	$\bar{a}$	$\ddot{a}$	*a*	*e*	*i*
8	*i*	1	R_1	$\frac{1}{2}$	1	2		
			Vowel reproduced	*e*	*i*	*i*		

TABLE II.

No.	Vowel Spoken.	R	Vowels Reproduced.
9	*ŏ ō*	1	R_1 . . . . . 1 2 Vowel reproduced . . *ŏ ō* *ō ou*
10	*ō ŏ*	1	R_1 . . . . . 1 2 Vowel reproduced . . *ō ŏ* *ou ō*
11	*ĕ ē ō*	1	R_1 . . . . . 1 2 3 Vowel reproduced . . *ĕ ē ō* *ē ē ou* *ē ē ă*
12	*ĕ ō ē*	1	R_1 . . . . . 1 2 3 Vowel reproduced . . *ĕ ō ē* *ē ou ē* *ē ou♯ ē*
13	*ĕ ŏ ē*	1	R_1 . . . . . 1 2 3 3½ Vowel reproduced . . *ĕ ŏ ē* *ē ō ē* *ē a ē* *ē a♯ ē*
14	*ō ē ē*	1	R_1 . . . . . 1 1½ 2 Vowel reproduced . . *ō ē ē* *ou ē ē* *ou♯ ē ē*
15	*ō ŏ ă*	1	R_1 . . . . . 1 2 3 Vowel reproduced . . *ō ŏ ă* *ou ō a* *ou♯ ă e*
16	*ŏ ō ă*	1	R_1 . . . . . 1 2 3 Vowel reproduced . . *ŏ ō ă* *ō ou a* *ō ă e*
17	*ă ŏ ō*	1	R_1 . . . . . 1 2 3 Vowel reproduced . . *ă ŏ ō* *a ō ou* *a♯ ō ou♯*
18	*ō ĕ ă ī ŏ*	1	R_1 . . . . . 1 2 3 Vowel reproduced . . *ō ĕ ă ī ŏ* *ou ē ă♯ ī♯ ō* *ou♯ ē ī a♯ ō*
19	*ō a ī ŏ ē*	1	R_1 . . . . . 1 2 3 Vowel reproduced . . *ō a ī ŏ ē* *ou a♯ ī ō ē* *ou♯ a♯ ī♯ ō ē*
20	*ŏ ō ä e i*	1	R_1 . . . . . 1 2 3 Vowel reproduced . . *ŏ ō ä e i* *ō ou a♯ e i* *ō ou♯ a♯ ī u♯*

In addition to what has already been said as to the conventional signs used by us to indicate the different vowel sounds, it should be stated that in the preceding tables and subsequent pages a ♯ following a vowel indicates a rise in its characteristic note, generally with an accompanying nasal quality Thus in (1), (2), (12), and elsewhere, the sound denoted by *ou*♯ is nasal. In (1) it approaches a nasal *ä*. In (13), and elsewhere, the sound denoted by *a*♯ lies between *a* and *e*, and closely approaches or even passes into the French nasal *in*. The sound *ā*♯ in (18) approaches *ī*. The sound *ī*♯ in (18) is strongly nasal in quality. The *u*♯ in (20), however, is not at all nasal, but is a very high *u* with a resonance note much higher than that of *ī*.

Several series of experiments were also tried in which a number of vowel sounds in succession were impressed upon the cylinder, and sub-

sequently reproduced at different speeds — a method which enables one to compare more readily the changes in the various vowels with one another. The results of these comparisons are found in Table II.

A careful comparison of the various changes indicated in the preceding tables will show a close accordance between the results of different experiments. But there will be noticed a few apparent discrepancies. Thus in (15) $\bar{o}$ rises to *ou*# and in (16) to $\ddot{a}$; in (15) $\ddot{o}$ rises to $\mathring{a}$, and in (16) to $\bar{o}$, while $\bar{a}$ rises to *e* in both series. These and such other like results as exist are due chiefly to the fact that it was difficult to measure the speed with any great exactness at the higher rates, or to maintain this speed absolutely uniform, and a slight increase in speed would suffice to change the results as stated in (15) to those of (16). The vowel $\bar{a}$ sustains the same change in each, notwithstanding this difference in speed, because the *e* into which it changes is more persistent than the other vowels in the series, as will be more fully explained a little later. It will also be instructive to compare (16) with (17). The $\bar{a}$ in the former rises to *e* on passing from one to three revolutions, while in the latter it rises only to *a*#, which sound would have passed into *e* on a slight increase of speed. In (16) the speed was doubtless a trifle higher than in (17) as well as in (15).

It must also be remembered that at certain stages a sound will be on the point of passing from one recognized vowel into another, so that it may be difficult to denote its sound exactly by any of the conventional signs usually employed. For this reason it might be preferable to substitute the symbols used by Mr. Melville Bell in his "Visible Speech."

Furthermore, we have noticed in some cases that a very trifling difference in the quality of the vowel impressed upon the cylinder at a low speed may cause a decided change in the vowel sound given out at a considerably higher speed. Thus, the vowel *e* reproduced at increased speeds passes into a high $\bar{\imath}$ and then into *i*. But if a series of *e*'s be spoken into the instrument, it is possible to find a speed of reproduction such that some of them are heard as $\bar{\imath}$'s and some as *i*'s. On raising the speed the $\bar{\imath}$'s tend to rise to *i*, and on lowering it the *i*'s tend to fall to $\bar{\imath}$.

Some interesting peculiarities of different vowels were observed in the course of our experiments.

It was noticed that, in several cases where the vowel seemed to have quite lost its peculiar quality, there was nevertheless a certain

reminiscence, so to speak, of its original character remaining. This appeared to be due to the logographic differences among the various vowels. Of course, the logographic characteristics of any vowel are not altered by the speed at which the sound is reproduced, so that in many cases we necessarily reproduce a sound with a characteristic resonance note belonging to one vowel and a logographic character belonging to another. Where the logographic character is clearly marked, this may enable one to recognize the vowel sound originally spoken into the phonograph, even though the characteristic resonance note is quite changed. This is especially true when the vowel forms part of a word.

There also appears to be a great difference among different vowels in what we may call the persistence of their vowel character when the speed of reproduction is varied. Whereas some, as *ö*, *ō*, and *ä*, change their character completely on increasing the speed, say to double its original rate, others change far less. The vowel *ē* seems particularly persistent under a large change in speed. With it as with all vowels there is necessarily a shortening at higher speeds, as denoted in the tables by a dot placed under the letter; but apart from this the speed may be varied more than for any other vowel studied by us before any marked change in its quality appears.

In order to form some estimate of the extent to which the context would influence the judgment as to the character of a vowel sound, the experiment was tried of reproducing at different speeds a sentence or verse spoken into the instrument. Thus the words from a negro melody containing the vowel *ō* many times repeated were spoken, as follows:

"Roll, Jordan, roll!
Roll, Jordan, roll!
I want to go to heaven when I die
To hear old Jordan roll."

These words were impressed upon the cylinder at a speed of three revolutions per second, and were reproduced at speeds of two revolutions and one revolution per second respectively, with the following results. At two revolutions the *ō*'s were in all cases plainly recognizable though lengthened; but at one revolution the quality was completely altered, *ō* having become changed to *ö* in all cases. Like results were observed in other sentences containing the vowel *ō*.

In like manner the sentence "This was the noblest Roman of them all" was impressed upon the cylinder at a speed of one revolution. Reproduced at two revolutions, the *ō*'s had a sound which closely ap-

proached *u*. Lowering the speed slightly changed it to a very short *ŏ;* and raising the speed slightly, to a clear *u*. At three revolutions the quality of all the vowels was so completely changed that the sentence was entirely unintelligible even to one knowing what it really was, the rapidity of the speech, as reproduced, however, contributing largely to this lack of intelligibility. To avoid this latter source of difficulty, the same sentence was spoken into the instrument at a speed of two revolutions, and reproduced at one revolution and also at three revolutions. At the lower speed the *i* in "this" changed to *a*, so that, the *s* in "this" being rather indistinct, the word seemed almost to have changed to "that." But the *ŏ*'s, while deepened in quality, did not apparently actually change to *ö*. Lowering the speed still more caused a closer approach to this, but the *ō* quality still seemed to persist. This was doubtless due in part to the association of the sound with the word, and in part to the acoustic effects due to logographic pressure, and to the connection of the vowel with the preceding consonants. To study these, the same sentence, preceded by four *ŏ*'s and followed by the same number, was spoken at two revolutions and reproduced at one revolution. The separate *ŏ*'s seemed to fall to *ö*, and there was likewise a perceptible fall in the same sounds in the body of the sentence, but these seemed still to retain their *ō* sound. To test the matter still further, the same sentence with the *ŏ*'s mispronounced was spoken into the phonograph, at a speed of one revolution, as follows: "This was the nöblest Röman of them all." On reproducing it at two revolutions the *ŏ*'s changed to *ō*, and the sentence was clearly heard with the mispronounced words rectified, and as distinct as if they had been properly pronounced when impressed upon the cylinder, and reproduced with the same speed of the cylinder as when uttered. Lowering the speed below one revolution, the *ö* sounds became still deeper and clearer.

As the vowels *ō* and *ö* are more persistent in their character than some others, a similar experiment to those already described was tried with the line "Though the harbor bar be moaning." This was impressed upon the cylinder at a speed of one revolution per second. Reproduced at two revolutions, the words "härbor bär" became "harbor bar" (*a* as in *hat*), and at three revolutions the *ă*'s in the same words assumed a nasal quality somewhat approaching the French nasal *in*.

The further experiment was performed of sounding the five vowels *ā ē ī ō ū* successively into the cylinder when this made one revolution

per second, and reproducing them at three revolutions. It was found that the quality of the different vowels was altered so that they were unrecognizable by one ignorant of the sounds which had actually been spoken by the voice. The same result was reached with the vowels *ä e ē ō ö*, and also with *ö ō ä e i*. The last mentioned series, which is No. 20 in the tables, was impressed upon the cylinder at a speed of one revolution, and reproduced at two and at three revolutions, approximately. At two revolutions the series seemed to have changed to *ō ou a♯ e i*, the *a♯* closely approaching the French nasal *in*. At three revolutions the sounds heard were *ō ou♯ a♯ ī u♯*, the *a♯* being a clear nasal *in* and the *u♯* a very short *u* with a high resonance note.

The limitations in speed of the phonograph cylinder, as the instrument is constructed for practical purposes, have thus far prevented us from carrying the range of changes in the pitch of the reproduced sounds as far as is desirable. This defect we purpose to remedy by suitable modifications in the driving gear of the apparatus. For reasons already explained, it is also desirable to measure the relative rates of rotation more accurately than we have been able to do with the commercial form of the phonograph.

We hope that we may be able to continue this investigation by a more systematic study of the behavior of the reproduced vowel sounds, and likewise to consider the effect of changed pitch in reproduction upon the various consonantal sounds.

In connection with the present subject, it is interesting to consider the unconscious testimony to the existence of different characteristic resonance notes for the different vowels which is given by various onomatopoetic words. The words used to denote various sounds form an excellent example, as will appear from the following list of a few such words in which the pitch of the sound denoted is higher as the list proceeds: boom, gurgle, roll, toll, roar, slump, thump, crash, smash, crack, snap, bang, jingle, ring, hiss. It will be observed that the vowels in the later words are those with higher resonance notes.

ROGERS LABORATORY OF PHYSICS,
May, 1892.

THE STUDY OF ARCHITECTURE.

By FRANCIS W. CHANDLER, Professor of Architecture.

Received March 4, 1893.

Vitruvius perceived clearly the many-sidedness of architecture when he enumerated the varied qualifications which he considered necessary for the finished architect. To reach his high standard to-day, even if nothing more was required, would tax the powers of the best of us to the utmost. But could he return and see the progress of civilization during the centuries since he wrote his first specification, and note the numberless additional burdens that have been placed on the architect's shoulders in consequence, it would surely seem to him well-nigh impossible to find any single person capable of undertaking so much. In this generation alone we have seen whole trades come into existence — trades which at the beginning simply catered to the luxury of the few rich, but have now become a necessity to the whole people, as, for instance, those which have to do with sanitary science, electrical engineering, heating, and ventilation; while others, as iron construction and decoration, have so expanded as practically to cover new fields. These add much to the comfort and attractiveness of our lives, but they also add immensely to the architect's labors, which even eighteen hundred years ago Vitruvius considered so exacting.

Glancing over the field of necessary operations for any architectural work, every one must be impressed, and most of all the architect, with the responsibility called for in this difficult profession.

So before beginning its study one should ask himself if he has the primary qualifications for success, and in what order they should be considered. The student must remember that he has no clear field before him. Competition is steadily increasing, for no profession offers greater attractions to the cultured scientific mind.

First of all he must be strongly attracted to this study. He must then bring industry to bear upon his work, and if he has common sense, which is the one universally appreciated element, he should feel

his chances of success to be fair. If after this he develops genius, he may be thankful.

Professional training may be divided into two parts — the technical and the artistic; in the former, science and mathematics are the principal studies; in the latter, drawing, designing, and study of historical precedent. In regard to general culture, its value is too self-evident to need a special appeal. It is impossible for the architect to have too broad a culture. He must be able to enter into the interests of his cultivated client, with whom no profession can have more intimate relations. Any work in the Fine Arts will be better done by a man who has a broad horizon and generous views of life.

The study of scientific construction is a necessary part of an architect's training. Construction and design are inseparable, and must be studied together. All experience in the architectural practice of to-day shows that the architect should not only be a skilled artist, but also be so scientifically trained as at least to appreciate all constructive questions. In the great office buildings, built for investment, there is no more important factor to remember than that only enough material shall be used to insure their stability, or else capital is wasted. Science tells us the nature of materials, and materials must govern design. For example, engineering practically discovered the use of iron as a building material; science has shown us the exact conditions for its use; and this knowledge of using fitting material and designing in accordance with it is a fundamental principle of architecture. A man who does not give due weight to construction cannot design, because in true architecture the artistic design simply reënforces and makes intelligent the construction. Neither can a great architectural work be thoroughly appreciated except by one who has been so scientifically trained as to understand the difficulties overcome, as well as the skill with which the design tells the story.

The study of history is all important. One must understand and follow the growth of a great style, from its beginning to its culmination and to its final merging into the next epoch. For the history of architecture is like a series of waves, the crests the perfected styles, and the hollows the transition from the one into the next following. In this study of architectural history one great fact stands forth — that these monuments have character and appeal to us strongly because they are the results of the effort of whole ages, rather than of any individual. There was no question with the old masters what

style was best adapted for the immediate work in hand; there was only the one style, and because they had grown up in its traditions they worked in it so naturally that their work could not be otherwise than good. In the old time originality confined itself to adapting good work, when seen, to the objects in hand, preserving the life and spirit of the original, which were its supreme attractions.

Every great style tells the same story. Even the Gothic, so commonly thought to have been called into life because connected with the religious awakening of the Middle Ages, owes its splendid results rather to the fact that this great movement took place at that time. The style was not used solely for religious purposes. There was no difference in the detail of molding or carving used for cathedral or other building — the same grotesque forms were to be found in the one as in the other. The difference was simply in degree of richness, there being more money for the cathedral than for any other building. When the Renaissance came, there was the opening up of universal knowledge and intercourse. Until then all architectural influences were practically local. Now the whole world is open to us to choose our model from, which before could not be farther away than in the next village.

Here is the modern problem — a big world with its treasure at our command. The same processes for design have to be gone through with now as in earlier times. We can found our work on Gothic or Renaissance. We can be eclectic; there is no law against it, but probably the work of any individual architect will be better if it is confined to a limited field of study. I recommend you as students to the most careful, solid, and persevering study of the Classic and Renaissance work. Because in the Orders culminated all architecture before them, and in the Orders was the birth of the great styles that came after. Because there is no more interesting period of history, and especially architectural, than that of the Italian Renaissance. Because there is no phase of the world's architecture of more interest to us as a nation, since it is so readily adapted to our needs. Because it requires learning, historical knowledge, and great accuracy. It involves all the fundamental principles of design, and there is no concealing of errors as in the more picturesque styles.

After you leave school you must meet the world in your own way, but if you have had a solid training in balance, proportion, light and shade, scale, color, etc., in a style requiring the nicest study of all of

these, you can be trusted to become eclectic or to work in any style you may ally yourself with.

The value of a good library cannot be overestimated, and the opportunity to use one should never be neglected. The use of such libraries as are a part of our principal architectural schools is an education in itself; there can be no end to the profitable labor that may be expended there. The student's sketch-book must be ever at hand. He will be adding constantly to his stock of architectural precedent for future use, as well as to his ability in drawing, and let him remember that designing is a natural sequence of good drawing, and the greater his facility in this the less willing he will be to let a design go forth until he is satisfied that it is his best.

Besides his drawing, he must learn to analyze for himself; he must not be satisfied with the mere fact that a building pleases him, or the reverse, he must find out why it is so, and be able to express the reasons. This is the true spirit of criticism. He should ask himself: Is it the harmonious proportion, or effective details, or the nice balance of light and shade? etc., etc. This habit of analysis is of the greatest importance, and the student will find he is storing his mind with certain rules which will be of great service in his future work, and all the more valuable because they have been thought out by himself and not accepted secondhand. Do your own thinking; study the old work; see in your own mind how you would adapt it to the present time, preserving its old spirit.

There is one other important study too much neglected — that of the arts of Painting and Sculpture in their relation to Architecture. Every good style has inevitably called to its aid the sister arts, and every architect should so understand them that when present in his work they should be an integral part of his design.

It is often said that it is an open question whether Michelangelo or Raphael was greater as painter, architect, or sculptor, and that it is hopeless to aspire to do as good work as theirs; but as we study our history and these artists' work and think for ourselves, we shall easily see that they were not equally good in all, that architecture was much the least part of their strength. In fact, Mr. Symonds speaks of Michelangelo as continually protesting that architecture was not his trade.

We shall see that such men as Brunelleschi, Alberti, or Bramante, who did not aspire to be great painters or sculptors, were greater in

architecture than Michelangelo or Raphael, but at the same time they were so at home in painting and sculpture that they knew how to heighten the effect of their work by the aid of these arts, and knew exactly what such painting or sculpture should be. It was because painters and sculptors in those days were called into being by architecture that they understood the art of the architect so well, that there was perfect harmony among the three. And it is from this point of view that we must get back to the old way of doing work. Until architect, painter, and sculptor are intimately associated again, studying each other's art, advising one another, working together for the good of all instead of the individual, we cannot have perfect architecture.

> One science only will one genius fit:
> So vast is art, so narrow human wit.

So while we only attempt to be expert in our own art, let us understand so well the language of the others as to make it a part of our own. This close alliance of the arts is seen in all the great styles, from the earliest times, in the painting and hieroglyphics of the Egyptian walls and columns, the friezes of the Greek temples, the mosaics of the Byzantine churches, the frescoes of the Italian Gothic, and the noble portals and stained glass windows of the Western and Northern mediæval Gothic. This close alliance is shown better, perhaps, in Gothic architecture than in any other style. In the South, the heat and brilliant sunshine called for cool and shady retreat; windows were reduced to the smallest size, and the great wall spaces called for color, and on these the painters exercised their art; they were the only fields for their talent until the Renaissance. Stained glass was to the Western and Northern Gothic what fresco was to the Southern. The gloomier, colder climate called for more sun to be let into their buildings, and the great windows were at once seized upon as the proper field for decoration, and they were made larger and larger until there was no wall space left. In all these instances the design included the three arts, and not one could be taken away without great injury to the whole.

I write this so that the young architect may see how much there is for him to do to help create a school to make architecture a living art as it was in the olden time. He must have the highest ideal and aim to excel in his own art. He must form a close broth-

erhood with the painter and sculptor. He must always remember that his education is never complete. He must not think because he has ended his course at school he is qualified to practice architecture. His degree can only prove that he is solidly prepared in the fundamental principles of his profession; that he can stand on his own feet, and knows in what direction to walk. He must next have the training which is found in the office of a busy architect, under experienced men, on actual work, and with skilled mechanics. The lessons thus learned are invaluable and never forgotten. This is an experience which must be had to give one the right confidence in himself and to obtain the confidence of the public.

And until this training has been thorough and prolonged our friend should resist every inclination to join that body of young architects whose work may be fairly criticised by the two words, "insufficient training." So when the time does come for him to call himself a professional architect, if he has a high ideal and is strong enough to live up to it, he will lead the public, and not be led by it.

THE ACTION OF COMPOUND DYNAMOS WHEN RUN IN PARALLEL.

By WILLIAM L. PUFFER, S.B.

Read March 23, 1893.

WHILE arranging some details of the wiring plan for connecting up two compounded railroad generators so that they could be tested for commercial efficiency, while under the conditions of full load, by one of the purely electrical methods my attention was drawn to the fact that the usual method of adjusting such dynamos so that they would give a constant potential at their terminals irrespective of the current flowing could not be a correct one unless the machines were exactly alike in all respects.

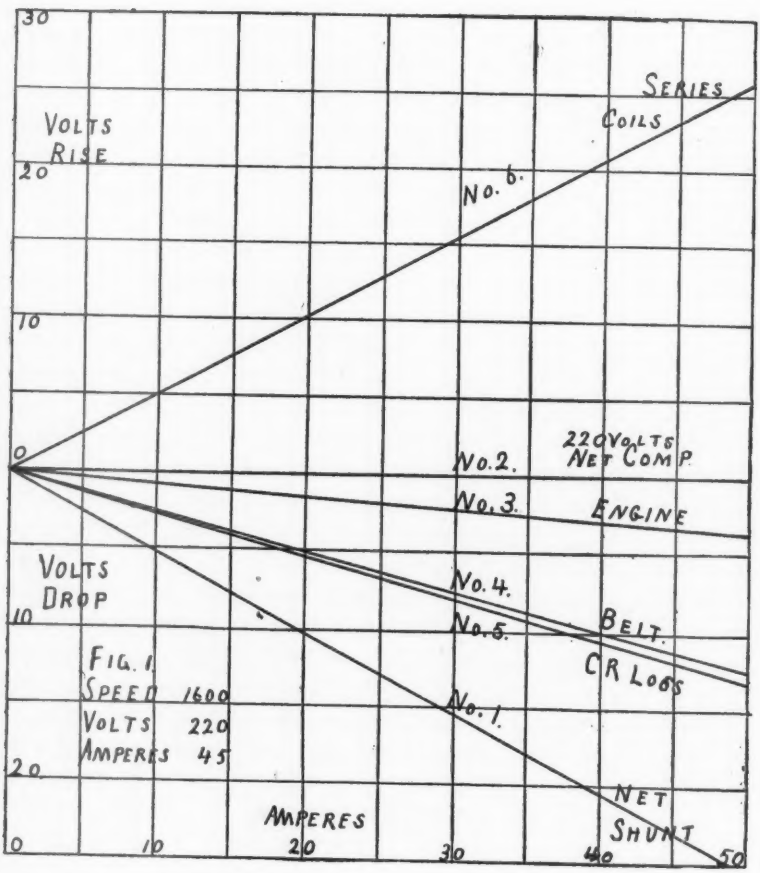
The general practice is to over-compound such generators, and then to experimentally shunt the series coils with a German silver ribbon until the desired "0 per cent. rise" is obtained; this is well enough for a single dynamo, but when two or more are in parallel, with their series coils also in parallel, the German silver shunts do not in any way aid the different dynamos in equalizing their load, and any original structural difference will cause the load to divide unequally. I found that in all of the power plants that I could then visit (winter of 1890–91) there was very decided evidence of this tendency to unequal division of the load, and it could readily be seen that some machines were always taking more than their share of an increase of load and tending to do too little when the load fell off. There seemed to be a very common knowledge of the trouble in making the dynamos work well together, but there seemed to be no attempt to help the matter, or, as far as I could find, any knowledge of where the fault was.

A year ago the Thomson-Houston Electric Company was so kind as to loan the Institute a pair of similar over-compounded motor-type dynamos which had been adjusted for "0 per cent. rise;" these dynamos were similar to the power generators of that company, and enabled

me to make a study of the action of compound generators connected in parallel. The dynamos were belt driven from the main shaft in the dynamo room of the Physical Department and were under good average running conditions. A short piece of shafting was arranged so that by slipping the pulleys slightly the two armature shafts could be mechanically connected, and therefore must at all times be at the same speed. Suitable water resistances connected to each machine were used for varying the output of the armatures. Double-pole jackknife switches of the type generally used were provided for connecting the two dynamos in parallel. A dead beat ammeter was placed in each armature circuit, and an Ayrton & Perry spring ammeter in the equalizing wire; a Weston voltmeter was used in connection with pressure wires to measure the voltage of either armature.

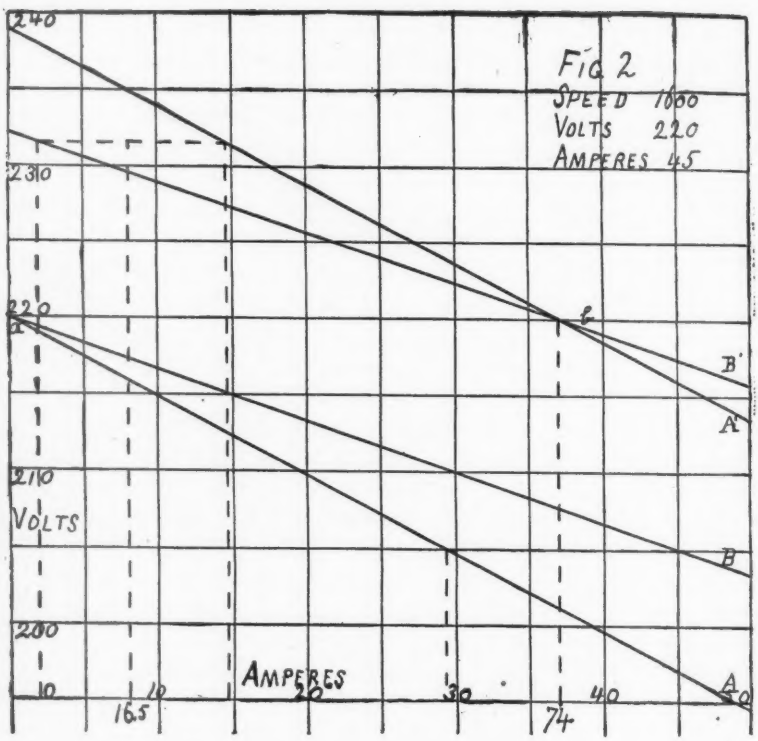
The object of this paper is not to describe these tests, but rather to explain a method of investigating the action of compound dynamos in parallel, and to point out the cause of some of the difficulties commonly met with as well as to show that it is comparatively a simple matter to avoid them; so that the results of these tests, although very interesting, will not be given except as explanatory examples.

Considering first the action of a single shunt dynamo driven by a belt from an engine doing no other work, if now the load be gradually increased to the maximum amount that can be safely carried, and if from time to time simultaneous values of the current and voltage be taken and plotted as in Figure 1, Curve 1 — for want of a better name let us call this the *net* characteristic curve of the combination — this curve would be a horizontal line (Curve 2) if it were not for the sum of a number of actions all of which tend to lower the electromotive force; beginning at the engine there is the usual fall of speed as the load increases, due simply to the action of the governor (Curve 3), the dynamo pulley lags behind more and more on account of the increasing slip of the belt as the transmitted power becomes greater, these two changes are plotted in Curve 4; in the dynamo armature there are the usual demagnetizing reactions which lower the electromotive force; and finally there is the fall of potential in the armature wires as well as all the necessary leads, fuses, ammeters, and connections up to the distribution point or bus bar where the voltmeter was connected (Curve 5). These separate losses may be plotted separately, and their sum will equal the amount that the net characteristic will fall below a horizontal line.


30
20
10
0
VOLTS RISE
SERIES COILS
No. 6.
220 VOLTS NET COMP
No. 2.
No. 3.
ENGINE
VOLTS DROP
No. 4.
No. 5.
BELT.
C R LOSS
No. 1.
NET SHUNT
FIG. 1
SPEED 1600
VOLTS 220
AMPERES 45
AMPERES
0
10
20
30
40
50

Inasmuch as the net characteristic in this combination is a very drooping one, it would be necessary to use hand or automatic means of adjusting the voltage as the current changes so as to keep the mains at the normal value — the effect of this regulation can be considered to be a raising or lowering of the net characteristic bodily without any material change in the inclination. Such regulation is always too late by at least the time necessary to produce a change of the indicating device, yet if this amount is small and the demand for current is not very variable such a combination is perfectly satisfactory, and even desirable, on account of the sudden fall of voltage on a short circuit which lessens very materially the shock to all parts of the system.

A second similar combination can be connected in parallel to this first one and the load divided between them — all that is necessary is to have the voltage of the incoming system very nearly equal to that of the bus bar or common point and then to close the switches. Evidently if the voltage of the new dynamo were just right no current could pass in either way, but if it were somewhat too high then a part of the total current would change from the old dynamo to the new one. If, for example, the new dynamo were x volts higher than the old, then the current through it would be of such value as would cause a fall of $\frac{1}{2}x$ on the net characteristic, and the current from the old dynamo would be smaller by the same amount. When the net characteristic is quite drooping, as is always the case with shunt dynamos, there is little or no danger of even overloading an armature when connecting it to the mains, in fact it is common practice in central stations to judge of the voltage of the new dynamo by the looks of its pilot lamp. If the two units (dynamo with its engine) have similar net characteristics, any change of load, sudden or not, will divide equally between them; but if, as usual, the characteristics are not similar this will not be the case, and we shall find that the unit with the steepest characteristic will not take its share of the work if the load increases, and will take more than its share with a decrease of load.



Let the lines A and B in Figure 2 represent the net characteristics of the two units; when the armatures are in parallel and delivering no current, let the voltage be brought to 220 volts, then the two lines are common, as at a. A sudden current of 74 ampères will cause the voltage to drop to 205, and B will deliver 45 and A 29 ampères. If now the load is equalized with 37 ampères in each armature, and the voltage brought up to 220 by the use of the regulating rheostats, the lines A and B are raised to A^1 and B^1 respectively, being common at b; now let the total current be diminished from 74 ampères to 16.5 ampères, a similar construction shows that the voltage will rise to 231.6 volts, and that A will deliver 14.5 ampères, and B 2 ampères.

When two dynamos with net characteristics like these are subject to a rapidly changing load, it is impossible to evenly divide the

current, and a balance has to be struck between the limits on the one hand of the dynamo A driving B as a motor — which will, of course, do no especial harm other than to waste energy in heating and sparking — and on the other hand of melting the fuses of dynamo B during an unusually heavy call for power, which might have been safely carried by the fuses if equally divided. It is plain that in this case the combination of the two dynamos is not double the capacity of either one, and the commercial efficiency is considerably lessened by the want of similarity of the net characteristics.

It is very desirable on many accounts to have a dynamo which will automatically maintain an approximately constant potential at the switch board irrespective of the amount of current flowing. We may add a series winding to the dynamo of just sufficient number of turns to give such a magnetizing effect as will produce a voltage which shall be at all times exactly equal and opposite to the combined effects of the change in engine speed, belt slip, armature reactions, and the drop of voltage due to the resistance of the armatures, lead wires, ammeter, safety devices, and the like, up to the bus bar (Figure 1, Curve 6). The net characteristics will now be made up of the sum of the individual effects, as shown in Figure 1, Curve 2, and the voltage at the switch board would be constant at all times were it not for the hysteresis of the iron in the magnets, which will very slightly prevent the instantaneous rising and falling of the effect of the series coils, and any change in resistance due to temperature change. The temperature change will be slow, and is corrected by an occasional change of the rheostat in the shunt coil circuit and can be neglected for the present.

Should it be necessary to use a second dynamo of exactly similar design, we cannot proceed as in the case of simple shunt dynamos, for this reason: if the new dynamo is at exactly the same voltage as the mains at the switch board when connected in parallel, the combination will be unstable because if for any cause the voltage of either dynamo varies a little, so that the new machine becomes ever so slightly a motor, the effect of the reverse current in its series coil will be to weaken still more the electro-motive force, which will allow an increasing current to flow until something burns out.

If, however, there is a third connection made so that the brushes as well as the terminals of the two dynamos are connected, it becomes impossible for this reversal to happen, and the machines will run per-

fectly under all changes of load. There are in use two ways of arranging the switches (Figure 4 and Figure 5), either of which is satisfactory; but the one shown in Figure 5 is better, as the idle machine is completely disconnected from the circuits.

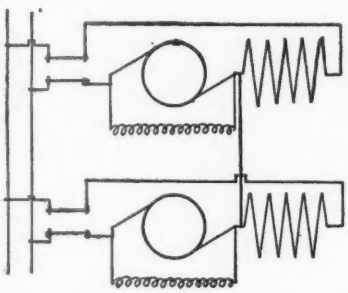


FIG. 4.

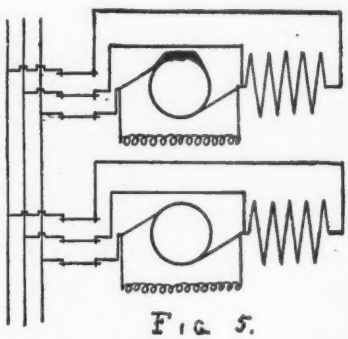


FIG. 5.

An examination of the components of the net characteristics (Figure 1, Curve 2) shows us that if the incoming dynamo be brought up to the voltage of the switch board and the switch closed, the load will instantly divide between the two dynamos with no disturbance or shock of any kind. Suppose, for instance, that the loaded machine is giving out 40 ampères, we see from the net shunt characteristic (Figure 1, Curve 1) that there is a drop of 20.5 volts, which is made up by the effect of the series coil (Curve 6), giving a terminal potential of 220 volts. When the new machine at 220 volts is switched in parallel we may first consider that one half the total current of 40 ampères passes through each of the parallel series coils, and from Curve 6 we see that the volts-rise is cut down from 20.5 to 10.2 in the first dynamo and raised from zero to 10.2 in the new one; from Curve 1 we see that for each dynamo this change of 10.2 volts just compensates for a current of 20 ampères through the armature circuits, and that the total load of 40 ampères at 220 volts will be equally divided between the dynamos.

The action of compound constant potential dynamos in parallel is generally misunderstood, and the equalizing connection is credited with a remarkable power of control over the output of such dynamos which it does not and cannot have, as can be seen by watching the dynamos

while at work as well as by examination of the makeup of the net characteristic (Figure 1). The common idea is that the equalizer has the property of compelling a lagging dynamo to take its share of the work, and we hear of the wonderful power of control which it has even over dynamos of different types and sizes running under somewhat different conditions. Now the real effect of the equalizer is to put the series coils in parallel, so that the total flow of current from the plant will divide between them inversely as their resistance without any regard as to whether this current comes from one armature alone or is divided among many, and hence it follows that it cannot in any way exercise even the slightest regulating effect on any one dynamo that it does not have over all the rest. The armatures themselves are running in parallel under the usual conditions of ordinary shunt dynamos, and the total current will divide between them under the same laws that would hold if there were no series coils at all and the current were taken from the two main wires to which the brushes are connected, as has been already pointed out in a previous part of this article.

The net characteristic of the plant is then a falling one as far as the armatures are concerned, to which has been added the automatic regulation of the parallel series coils which act together in proportion to the total flow of current from the station; and if these series coils are all alike in effect, each dynamo will have its voltage altered by an equal amount in proportion to the output of the station, but each armature will not do its share of the work unless all the net falling characteristics are exactly similar.

In a plant of such dynamos each driven by its own engine it is most likely that the net falling characteristics of the armatures will not all have the same steepness, and consequently a fluctuating load will not be shared equally by the dynamos; but it is possible to so arrange things that the series coils do not all act equally on the armatures, and if the resistances of the series coils are slightly changed by the addition of a little German silver or copper ribbon so that the total flow of current divides between the different series coils in such a proportion that the individual net armature characteristics are raised by just the right amount, we again have a plant in which a fluctuating load will divide equally among the different dynamos. The same effect may be produced by the addition of a small resistance in the armature circuit of any dynamo which takes more than its share of an increase

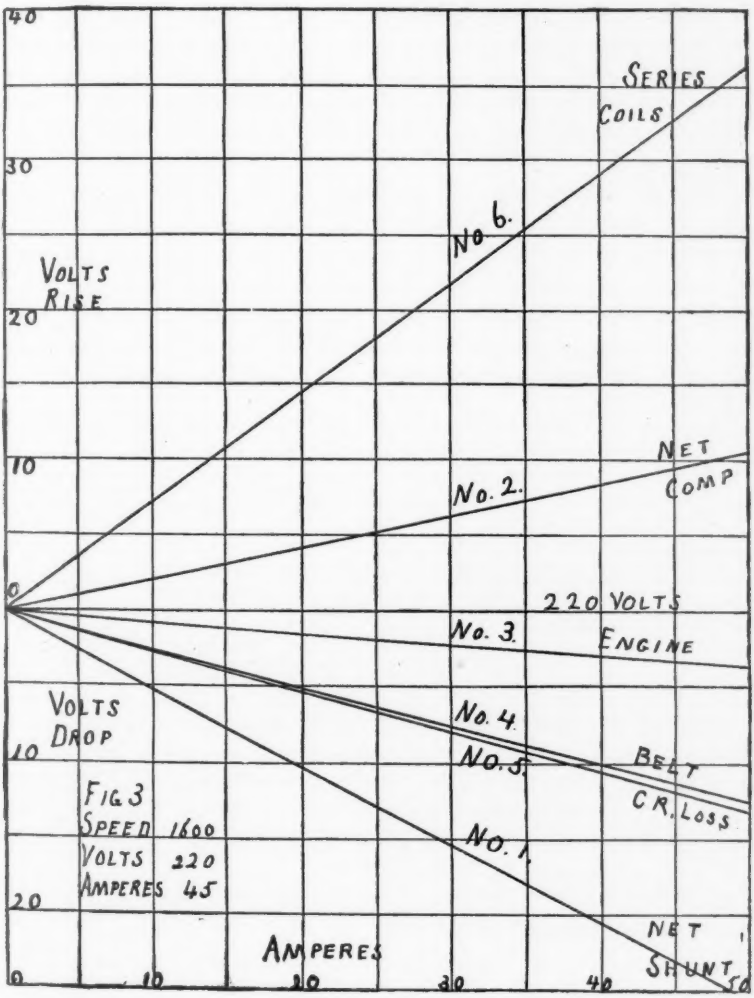
of load. A number of machines so adjusted will run together perfectly, and there will be no change of voltage or any difficulty experienced in cutting in or out by the use of the ordinary two or three-pole switch; the only precaution to be observed is to have the voltage of a new machine nearly that of the bus bars, for then, when the series coil is put in parallel with all other series coils, it will be traversed by such a part of the total flow of current as will be sufficient to raise the voltage of the armature enough to enable it to deliver its share of the total output.

If a dynamo is to be cut out it will not do to reduce its load first by the use of the resistance in the field circuit, because by this process its load is transferred to the other dynamo armatures and the station voltage will consequently fall somewhat, because the series coils are not proportionately increased. This fall of voltage may or may not be permissible, and is avoided if the switch is opened while the dynamo has its share of the load.

Sometimes it is desirable to have a dynamo which will maintain a constant potential at a point some distance from the switch board; in this case the series coils will have a few more turns, so as to make up for the fall of potential in the mains; and in Figure 3 will be found the component curves for a dynamo adjusted for approximately "5 per cent. rise." Curve 1 may be called the "net shunt" falling characteristic made up of the sum of the effects due to the engine change, belt slip, and the fall of potential in the armature circuits represented respectively by the Curves 3, 4, and 5. Curve 6 shows the rise of voltage due to the current in the series coils, and is greater than the total drop Curve 1 by an amount plotted as Curve 2, which is the net characteristic of the over-compounded dynamo.

Should the demand for current exceed the capacity of one dynamo, the addition of a duplicate machine will render it impossible to maintain a constant potential at the distant center unless both dynamos are run all the time; for while 45 ampères on one dynamo will cause a net rise at the switch board of 9.5 volts, the same total current furnished by the pair will only produce a rise of 4.75 volts.

If this want of exact regulation does not require the constant running of two dynamos at times of light load, we meet greater troubles in the process of adding the second unit when the load is too heavy for the first one. From the data given in Figure 3 it is possible to see what will happen under any given conditions when the machines


40
30
20
10
0
10
20
VOLTS RISE
VOLTS DROP
SERIES COILS
No 6.
NET COMP
No. 2.
220 VOLTS
No. 3.
ENGINE
No. 4.
No. 5.
BELT CR. LOSS
No. 1.
NET SHUNT
FIG 3
SPEED 1600
VOLTS 220
AMPERES 45
AMPERES
0
10
20
30
40
50

are put in parallel. I have experimentally verified this method of predicting the actions of compound dynamos, and find it exact enough for all practical purposes.

Suppose one dynamo is loaded, what will be the effect if we connect a new one when its voltage is lower, the same as, or higher than the switch board? I will take from my notebook the results of some experiments on two dynamos with characteristic curves like Figure 3, first giving the observed results and then calculating them from the curves.

The armatures were mechanically coupled and therefore at same speed. Voltage of each was 222; 30 ampères were taken from No. 2 dynamo and voltage rose to 228, while that of No. 1 fell to 212; then by a double-pole switch No. 1 was put in parallel. Momentarily No. 2 tended to overload and drive No. 1 as a motor, but in a few seconds the load became steady at a voltage of 222, No. 1 furnishing 18 and No. 2, 12 ampères. Now by calculation from curves of Figure 3:

No. 1.	No. 2.	
222.	222.	Volts at switch board with no load.
— 7.5	— 7.5	Curve 4. Drop due to speed change when a current of 30 ampères was taken from No. 2.
214.5	214.5	
	— 8.	Curve 5. Armature drop with 30 ampères.
	206.5	
	+ 21.5	Curve 6. Rise from 30 ampères in series coils.
	228.0	Switch board voltage with 30 ampères output.

Put in parallel with same load, so no change is to be made for speed change. From Curve 6 we see that the change of half of the current from the series coil of No. 2 to No. 1 will raise No. 1.

No. 1.	No. 2.	
214.5	228.0	No. 1 with no load and 30 ampères on No. 2 and then put in parallel.
+ 12.0	— 12.0	Curve 6. Change in voltage with change of half current from series coils of No. 2 to series coils of No. 1.
226.5	216.0	
— 4.	+ 4.	Curve 5. Suppose each armature carried one half the current then there would be a drop in No. 1 and a rise in No. 2.
222.5	220.0	

We must now add a current to the highest voltage dynamo, or No. 1, that will cause a drop of one half of 222.5 — 220 volts, which from Curve 5 will be 4.7 ampères.

Then the voltage of the combination will be 221.2; and dynamo 1 will deliver $15 + 4.7 = 19.7$ ampères, and dynamo 2, $15 - 4.7 = 10.3$ ampères.

Calculated 19.7 ampères, dynamo 1.	10.3 ampères, dynamo 2.	Voltage of 221.2.
Measured 18 ampères, dynamo 1.	12 ampères, dynamo 2.	Voltage of 222.

Take, for another example, the case when one of these dynamos was at full load and the new machine was brought up to exact voltage and then put in parallel, and applying these methods we shall see that it may happen that all current may be cut off by the melting of a fuse.

Dynamo No. 1 at 220 volts and no load, then as the load of 45 ampères comes on, the switch board voltage will be about 230 volts.

220	
— 11.2	Drop due to load. Curve 4.
208.8	
— 11.7	Drop in armature. Curve 5.
197.1	
+ 32.5	Rise from series coil. Curve 6.
229.6	Volts at switch board.

Here the switch is closed.

No. 1.		No. 2.	
229.6		229.6	
— 16.2	22½ ampères in series coil. Curve 6	+ 16.2	
213.4		245.8	Armature voltage.
+ 11.7	Curve 5, to find internal voltage.		
225.1	Armature voltage.		

245.8	Armature voltage No. 2.
225.1	Armature voltage No. 1.
20.7	Difference of armature voltages.
11.7	Drop in No. 2 with 45 ampères.
2) 9.0	Acting to send reverse current through No. 1.
4.5	Curve 5 corresponds to current of about 17 ampères.

245.8	Armature voltage No. 2.
— 17.0	Drop with 62 ampères. Curve 5.
228.8	Switch board voltage.

Dynamo No. 1, which was loaded, has a reverse current of 17 ampères and is driven as a motor, while the new dynamo carries the load and is 17 ampères beyond its rated capacity. We see that the switch board voltage practically does not change under these conditions, but to offset this there is the sudden change of a loaded dynamo

into a partially loaded motor and an overload on the incoming dynamo. Such changes would be accompanied by much sparking at the brushes and the liability of thrown belts or blown fuses. Then we may say that if the new dynamo is of lower voltage when connected the voltage will change considerably, but there will be no shock to the dynamos; if the new dynamo is at the same voltage then the voltage will remain about constant and the armatures will receive a shock; if the new machine is still higher, then the shock will be very severe and the voltage will rise. I had no time for taking readings on the last experiment, but I did notice that the needle of a 150-ampère instrument was out of sight before a switch could be opened.

There is a very safe and simple method of throwing in a new dynamo, which does not, however, prevent a change in the switch board voltage unless a special switch is used, as shown in Figure 6, con-

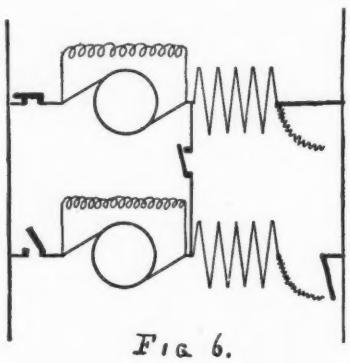


FIG. 6.

structed in such a way that the equalizing connection is first made and then the outside end of the series coil gradually connected by a switch with a few resistance points in it, while at the same time the magnetizing effect of the shunt coil of the loaded dynamo is increased to make up for the loss in the series coil. In this way the series coils can be put in parallel with no jump in the voltage. If, however, there are many similar dynamos in the plant, it might be that the change produced by throwing in a series coil without its armature would not produce a greater change than would be allowable; in such a case the safest way is to connect first the series coils, then rapidly adjust the armature voltage by the voltmeter, or, if in a great hurry, by the looks

of the pilot lamps, and then close the armature switch, well knowing that the steep net falling characteristic of the armature circuit will prevent an overload.

The common three-pole switch generally used can easily be changed so as to admit of working in this way by cutting through the top of the insulating bushing and putting a separate handle on the blade which closes the armature lead to the bus wire; then pulling the ordinary handle out will open all blades at once, but pushing it in will only connect the series coils, leaving the armature circuit open. If the wiring is so that the series coils are permanently connected and a new dynamo is thrown in by a single-pole switch, we have here a very wide range of voltages for the new dynamo, and pilot lamps may be used to judge the voltage. We have two bus bars with all the series coils joined between them; evidently, then, the total current flowing from bar to bar will simply divide between these coils inversely as their respective resistances, and we shall, in consequence, have the voltage of the armature bus bars rising and falling with the total current from the plant; and if the machines are similar all of the armature voltages will rise and fall together. If this is so, and it cannot be otherwise, these armatures are to be considered simply as net falling characteristic armatures working in parallel between the equalizing bar and the third bus bar, and the division of the load between them will take place exactly as has been previously shown for common shunt dynamos, and therefore, inasmuch as we have a very decided net falling characteristic, there is but little danger of an overload on a new dynamo armature.

It is now clear that when we wish such dynamos to run together we must first adjust the resistances of all the series coils and connections, so that when a current is passing through them but not through the armatures, the armature voltages must be equally affected; and also see that the armature circuits are so arranged as to give the same net falling characteristics independent of the series coils. It is necessary for good compounding to have the brushes set once for all, and in all well-designed dynamos it is possible to find a point where there will be no excessive sparking. An easier although not so good a way to adjust is to find the best point for the lead and then alter the resistances of the series coils until all dynamos have the same net characteristics; but the rise of voltage due simply to the flow through all the series coils will in this case be different in different dynamos, and there will be a little more difficulty in adding a new dynamo, and a tendency to overload.

Nearly all of the compound dynamos in the market for the last few years are purposely built with too many turns in the series coil, and then a shunt of German silver is adjusted by trial at the factory until the voltage at the terminals shows the wished for "0 per cent. rise," or whatever it may be. Now for any one dynamo running under the conditions of the experimental trial this method is simple and perfectly correct; but when such dynamos are run together in multiple it is of no service, and has no effect on the relative actions of the series coils of the dynamos, because of the fact that all coils and all shunts become parallel conductors, and therefore traversed by currents inversely proportional to their resistances. These shunts then merely diminish the total flow of current through the series coils, but in no way do they serve to adjust the effect of the series coils relatively to each other. If it should happen that one dynamo was very much over-compounded and then shunted for the "0 per cent. rise," and another only very slightly over-compounded and consequently only slightly shunted, it is plain that when the shunted series coils are in parallel the shunts will have only the effect of affording a path for a part of the total flow of current, and consequently could be wired up in any convenient place on the switch board. These two above-mentioned dynamos would then be dissimilar over-compounded machines working in parallel, and in all probability an increasing load would be largely carried by the dynamo with most turns in the series coil, because an increase in total current flowing through the series coils would promote the voltage of this dynamo faster than that of the other. This will be the familiar condition we often see in power plants where the average load is equally divided, while an overload is taken quicker by the dynamo which takes the less at light loads, that is, the one in which the series coils have greatest effect.

In order to make such dynamos work properly it is best to examine the lead and the wiring, and, if possible, give the armatures similar net falling characteristics, and then, by the use of copper or German silver ribbon, slightly change the resistance of the series coils until all armatures are equally affected by the flow of current in the series coils; a single large shunt may be connected at any part of the bars to which the series coils are attached, or perhaps better each machine may have a shunt across the series connections at the switch board, on the dynamo side of the main three-pole switch, so that the total shunting capacity varies as it ought with the number of dynamos running.

After one of my lectures a few weeks ago two young men asked me for an explanation of what seemed to them a very strange phenomenon which always occurred when a large dynamo was cut out of service; and, as it is a very good practical example of the use of multiple characteristics as I have shown them, I will give it. In a railroad power house are about sixteen 100 horse power "0 per cent. rise" dynamos and one large 500 horse power "0 per cent. rise" dynamo, all provided with shunts. Ordinarily the machines all do well enough, but as the load gets light at night and the big one is cut out the voltage rises instantly about 30 volts in some unexplained manner. May not this be the reason. The series coil and shunt of the large dynamo are of so low resistance that they carry a large part of the total current in all the series coils and shunts. Now when the machine is to be cut out, the current in the armature is cut down by the rheostat in the shunt field circuit to as nearly as may be nothing; but this current is in this way slowly shifted to the other sixteen armatures, causing a slight fall in voltage due to the net falling armature characteristics, which drop is not counteracted by the series coils because there has been no change in the distribution of the total current. This slight fall is probably not especially noticeable, but the sudden jump comes when the series coils and shunt ribbon of the 500 horse power dynamo are cut out of circuit and the large current in them is instantly transferred to the series coils of the other smaller dynamos. If the switches were made to stand the arcing I doubt if there would be much change noticed if the dynamos were simply disconnected without gradually diminishing the armature current.

It has been supposed in this paper that there is no such a thing as time required to change the strength of dynamo magnets, and that there is no difference between the ascending and descending magnetizing curve of iron. These time effects will not come in for ordinary fluctuations if the net armature characteristics are similar, and consequently the required changes in all the magnets would be of the same amounts and would therefore take nearly the same time; for sudden changes like a short circuit it is not likely that the load would divide equally, but it would be very much nearer so than with the ordinary unadjusted dynamos, and a heavier short circuit could be burned out than with unadjusted dynamos, where some would rapidly overload and open their circuit breakers and thereby precipitate a general breakdown.

In large plants where more than one dynamo is driven by a single engine and there are several engines, it will be found of advantage to adjust each set of dynamos so that they will work well together, and then adjust each engine load for engine speed change. To do this, each dynamo on a single engine would have its series coil and shunt properly adjusted until, as far as that particular engine load is concerned, the load would be equally divided between the armatures ; then the sets of series coils corresponding to the different engines would be connected through a small resistance to the station bus bar, and we should find that the total load could be evenly divided between the engines. The arrangement of these resistances is indicated in Figure 7,

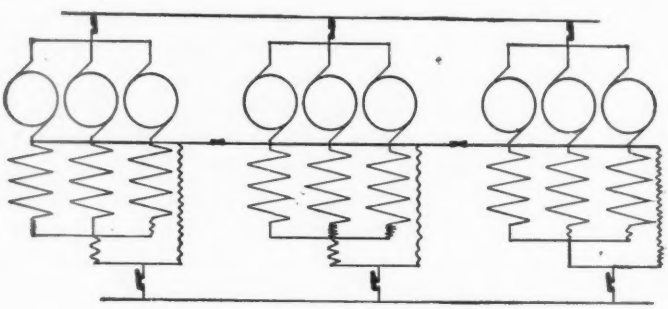


Fig. 7.

which shows three engines, each driving three dynamos by belts or any convenient way. The three series coils of each unit are adjusted so that a changing load will be equally shared by each dynamo, and then the three coils are shunted until the desired compounding is attained. It is now necessary to compensate for any difference there may be in the speed regulation of the engines or in the main belt slips by a slight change in the total resistance of the three sets of parallel series coils. There will be, of course, the usual precautions necessary when throwing in or cutting out a set of dynamos, and the most satisfactory way, if steady voltage is to be desired, will be to close the three large main switches at once, by steam or other power acting upon heavy switches built to stand the arcing of such currents, thus connecting simultaneously the three bus bars to the station main bars ; the same method should be used to disconnect when the time comes for stopping an engine.

In order to study the action of dynamos which were exactly similar in all respects except the magnetizing effects of their series coils, a number of turns of wire was wound upon the magnet spools of dynamo No. 2 and connected in series with the regular windings, and the resistance of the series coils of dynamo No. 1 was made equal to that of No. 2 by the addition of a length of copper wire. Each dynamo was then fitted with the usual German silver shunt of such resistance that the net result was a constant potential at the terminals.

The various curves of these dynamos are plotted in Figure 8, and may be described as follows: Curve 3 gives the fall of potential or drop in volts due simply to the fall in speed as the load on the dynamo increases, and is the same for each separately driven dynamo. Curve 4 gives the drop in volts in the total armature circuit from equalizer wire, which will be considered as a bus bar, to main bus bar, and does not include the drop in the series coils and connection to the bus bar, which is given separately in Curve 5.

Curve 0 is the sum of Curves 3, 4, and 5, and represents the total drop in each dynamo, when running independently, due to all reactions; while Curve 1 is the sum of 3 and 4, or the total drop if we consider the series coil as a part of the external circuit. Curves 7 and 8 show respectively the rise in voltage due to the current in the series coils of each dynamo, and it will be seen that for the same current value, dynamo No. 2 has a somewhat more powerful series coil. Curve 6, being the equal and opposite of Curve 0, shows the rise in volts which each dynamo must have in order to maintain a constant potential at its terminals; and therefore a horizontal line cutting Curve 6, as, for example, at the rated current of 45 ampères, will cut the Curves 7 and 8 at points whose corresponding current values are those which will produce the required magnetizing force, and the difference between these current values and the rated current must be carried by the shunts on the series coils.

The series coils of each dynamo were adjusted to a resistance of .15 ohm, and the series coil shunt of dynamo No. 1 had a resistance of about .60 ohm and would carry at full load about 9 ampères, leaving 36 ampères to produce the rise of 27 volts necessary to neutralize the total drop taken from Curve 6. To produce the same rise in No. 2 dynamo required a shunt of about .22 ohm carrying 18 ampères, leaving but 27 for the series coils.

These two dynamos are now in such a condition that according to

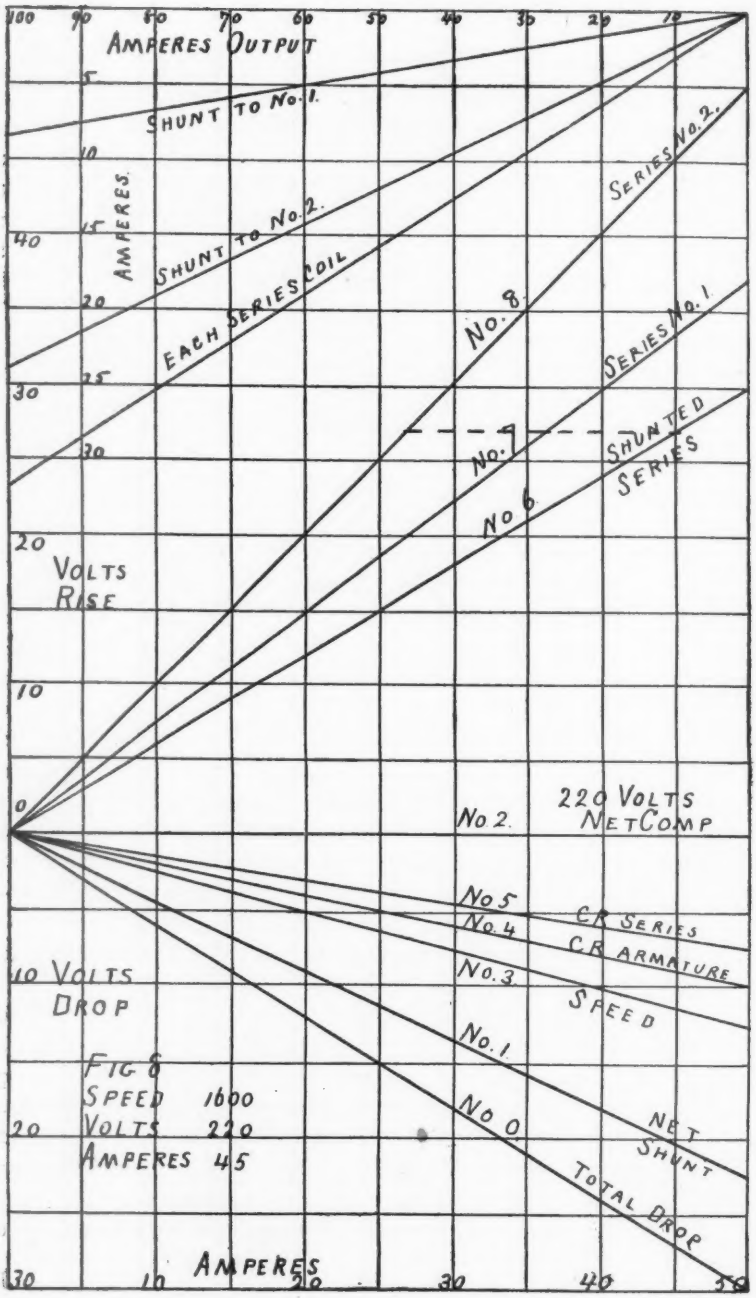


FIG 8
SPEED 1600
VOLTS 220
AMPERES 45

the usual practice it would be perfectly proper to run them in parallel with the expectation that everything would work well; however, such is not the case, as may be seen from the curves and as was proved by the actual effects obtained.

When the two series coils with their shunts are thrown in parallel the total flow of current through them will divide inversely as the resistances of the four circuits which are, as we have just seen, two series coils each of .15 ohm, one shunt of .60 ohm and one of .22 ohm. If we call the total current 100 these four circuits will carry respectively about 33.7, 33.7, 8.4, and 24.1, and as the total output of the two armatures may safely be 100 ampères, the above figures give the strength of current in these circuits.

At the top of Figure 8 is a scale reading from right to left up to 100 ampères, and near the left hand side a scale reading downwards up to 30 ampères; the three inclined lines enable us to read at once the actual current in the two shunts and the two series coils for any output of the dynamos when running in parallel.

It has already been shown that each dynamo is individually capable of maintaining a constant potential at the bus bars independently of the current flowing, and it has been stated that the dynamos will not work well in parallel. Suppose that the dynamos are connected in parallel at 220 volts under no load and that a current of 90 ampères, which is equal to the rated load of the two dynamos, is taken from the bus bars To find the currents in the series coils we find under 90 ampères total output that each series coil will carry 30.4 ampères; the shunt on No. 1, 7.6 ampères, and the shunt on No. 2, 21.6 ampères.

No. 1.	No. 2.	
220.	220.	Volts at no load.
+ 22.5	+ 30.2	Rise from Curves 7 and 8 at 30.4 ampères.
242.5	250.2	Total armature voltage.
	— 7.7	Fall of volts due to 17 ampères, Curve 1. No. 2
242.5	242.5	can deliver current producing a fall of 250.2 — 242.5 before No. 1 begins to act as a dynamo at all, and after that both armatures will divide the remainder, or 90 — 17 = 73, and the total drop is taken from Curve 1 for one half the difference or 36.5 ampères.
— 16.5	— 16.5	Drop with 36.5 ampères, Curve 1.
226.0	226.0	Armature bus bar voltage.
— 6.5	— 6.5	Drop in the series coil giving for the main bus
220.5	220.5	bars 220.5 volts with an output of 36.5 ampères from dynamo No. 1, and 53.5 from No. 2.

As an interesting example of the different degree of badness which may be produced when two individually well-adjusted dynamos are run in parallel, let us suppose that these two dynamos are placed in proper allignment and one large driving pulley slipped over the ends of the shafts, as is very often done, thus making the armatures run at the same speed with the same per cent. belt slip, which will bring the resultant voltage about the same as in the previous example.

No. 1	No. 2.	
220.	220.	Volts at no load.
22.5	+ 30.2	Rise from Curves 7 and 8 as before.
242.5	250.2	Total armature voltage.
	—7.7	Fall of volt due to 38 ampères. Curve 4.
242.5	242.5	Dynamo No. 2 must deliver a current producing a fall of volts equal to the difference of the armature voltages before No. 1 will deliver any current. The remaining current will divide equally, producing a fall found in Curve 4.
— 5.2	— 5.2	Fall with 26 ampères, Curve 4.
237.3	237.3	
— 6.5	— 6.5	Drop in series coils. Curve 5.
230.8	230.8	
— 11.2	— 11.2	Belt slip. Curve 3.
219.6	219.6	Voltage on main bus bars with an output of 26 ampères from dynamo No. 1 and 64 from No. 2.

COMPARATIVE TABLE.

	No. 1. Ampères.	No. 2. Ampères.	Volts.
Separate loads	45.	45.	220.
Parallel	36.5	53.5	220.5
Parallel at same speed	26.	64.	219.6

BOWLDERS FORMED IN SITU.

By GEORGE H. BARTON, S.B.

Received April 15, 1893.

The neighborhood of Boston furnishes many localities exceptionally well adapted for instruction in the field of classes in geology. Within a few minutes' to an hour's ride from Boston the student can reach many places, as, for instance, Roxbury, Somerville, Marblehead, and Nantasket, where illustrations of the various features of structural geology abound. The object of this paper is to call attention to a locality of exceptional interest for this latitude, exhibiting the formation of bowlders *in situ.*

It is well known that beyond the limits of the glaciated areas the surface rocks are decomposed to a considerable depth while they still retain their normal stratigraphic relations, and that veins of less decomposable material like quartz preserve their original position unchanged.

In some places where the elements of erosion have acted more rapidly than the process of decomposition, fragments of the original mass, more or less rounded, from which the decomposed portions have been washed away, are left upon the surface as bowlders.

Dr. T. Sterry Hunt, in a paper upon the "Decay of Crystalline Rocks,"[1] calls attention to the principal papers published upon this topic, and discusses at length the subject of decomposition. He arrives at the conclusion that the change took place when the atmosphere was in a highly carbonated condition and a climate very different from our present one prevailed.

L. S. Burbank[2] has emphasized strongly the formation of bowlders *in situ* as studied by him among the foothills of the Blue Ridge in North Carolina.

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[1] Mineral Physiology and Physiography, pp. 246–278.

[2] Proceedings of the Boston Society of Natural History, November 19, 1873.

Prof. C. F. Hart, in his work on the "Geology and Physical Geography of Brazil," and many others, might be cited on this subject.

Passing over the divide to the eastward of Butte, Montana, the writer noticed a large area of granitic rock, highly weathered, from which in many places the loose materials had been swept away, leaving subangular and rounded blocks scattered over the surface closely resembling the accumulations of the same forms by ice-action. Thus far reference has been made only to non-glaciated regions. Within the limits of the area formerly coated by the great continental ice-sheet, where nearly all the previously loosened material suffered transportation by its agency, accumulations of decomposed material *in situ* are comparatively rare.

When such accumulations are found, careful observation is necessary to determine whether these are remnants that were undisturbed by the action of the ice-sheet, or are the result of decomposition during post-glacial times. The place referred to in this paper is near the center of Medford, Massachusetts, north of the street leading to West Medford, and along Brook's Lane. The exposure consists of a part of the dike, which, outcropping at Granite Street and also near the Old Powder House in Somerville, continues north through Medford nearly to Spot Pond, Stoneham.

This dike has been referred to by nearly every writer upon the geology of Eastern Massachusetts, but has been most fully described by Dr. W. H. Hobbs.[1] This author describes the rock as essentially a diabase, "composed mainly of a plagioclase feldspar and an amphiboloid mineral with more or less biotite and pyrite." The rapid decomposition of the rock is due to "the amphiboloid mineral, causing a complete disintegration of the rock to a coarse feldspathic sand." "The products of alteration of the feldspar are calcite and a mineral which is probably kaolin."

The present recent exposures are immediately on the west side of Brook's Lane, and have been caused by excavations in connection with the building of new streets and grading around the new club house just erected. On the east side of a north-south ridge about forty feet high the dike rock is exposed in vertical section for many rods in length and varying in height from a few inches to twenty feet.

Throughout this entire section the rock is entirely decomposed on the vertical surface so that it readily crumbles in the fingers, though

[1] Bulletin of the Museum of Comparative Zoölogy, 16 (Geol. Series 2), 1–12.

occasionally a few patches of comparatively unchanged rock are visible, surrounded by the concentric structure common in decomposing diabase.

Occasionally, also, undecomposed veins still retain their original position, passing through the decomposed rock as shown near the extreme left of Figure 1, and also on the extreme right. Here, also, they are seen alike passing through the undecomposed fragment still *in situ* and the completely decomposed material above.

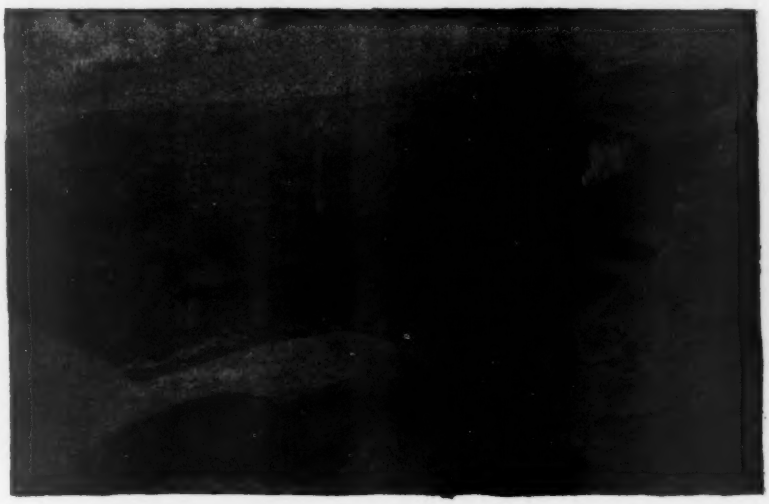

Fig. 1.

Along the larger portion of the exposure the looser decayed rock has fallen down, leaving exposed the masses still unchanged, or only slightly changed, many of which remain in place projecting from the bank, while others have fallen down and accumulated along the bottom. These latter appear very similar in form to the rounded and subangular glacial bowlders that are scattered over the surrounding country.

Fig. 2.

Figure 2 shows these characters very finely. The entire section shown in this, as in all three views with one exception to be noted, consists of the decomposed rock inclosing the unaltered fragments projecting from the mass and a row of the fallen fragments at the base.

The process of the formation of bowlder forms is shown in the mass above and to the left of the hand bag where two medium sized fragments, with a small V-shaped mass between, still retain their original position. The lines between these three portions show where decomposition has gone on along the joint cracks and the decayed material has been washed away. The same process is shown, though less distinctly, in the large mass a couple of yards to the right.

Fig. 3.

In Figure 3 the incipient breaking up of one large mass into four smaller ones is shown just to the left of the center. This view is of especial interest, however, as showing unmodified drift overlying a portion of the decayed rock. The contact can be easily traced as a nearly horizontal line from the extreme left, just above the quartered mass mentioned above, to a point just to the right of the center, where it suddenly changes and is continued as a vertical line to the surface. There is not sufficient evidence seen to indicate whether this is due to faulting or not. The unmodified drift is easily distinguished by the numerous small subangular fragments inclosed which are entirely unchanged.

In a few cases glacial striæ are to be seen crossing surfaces of unchanged rock, and also of the decomposed rock in immediate contact, in such a manner as to indicate that the now completely decomposed rock was unchanged when the striæ were formed. This would lead to the conclusion that the decomposition has taken place during postglacial time. This view is strengthened by the fact that portions of the rock exposed as outcrops have remained unchanged, while immediately adjacent portions which have been covered by the soil are highly decomposed. This last feature indicates that organic action is a strong factor in the production of decomposition.

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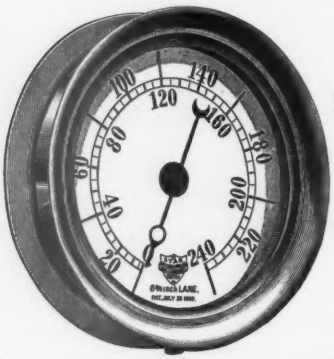

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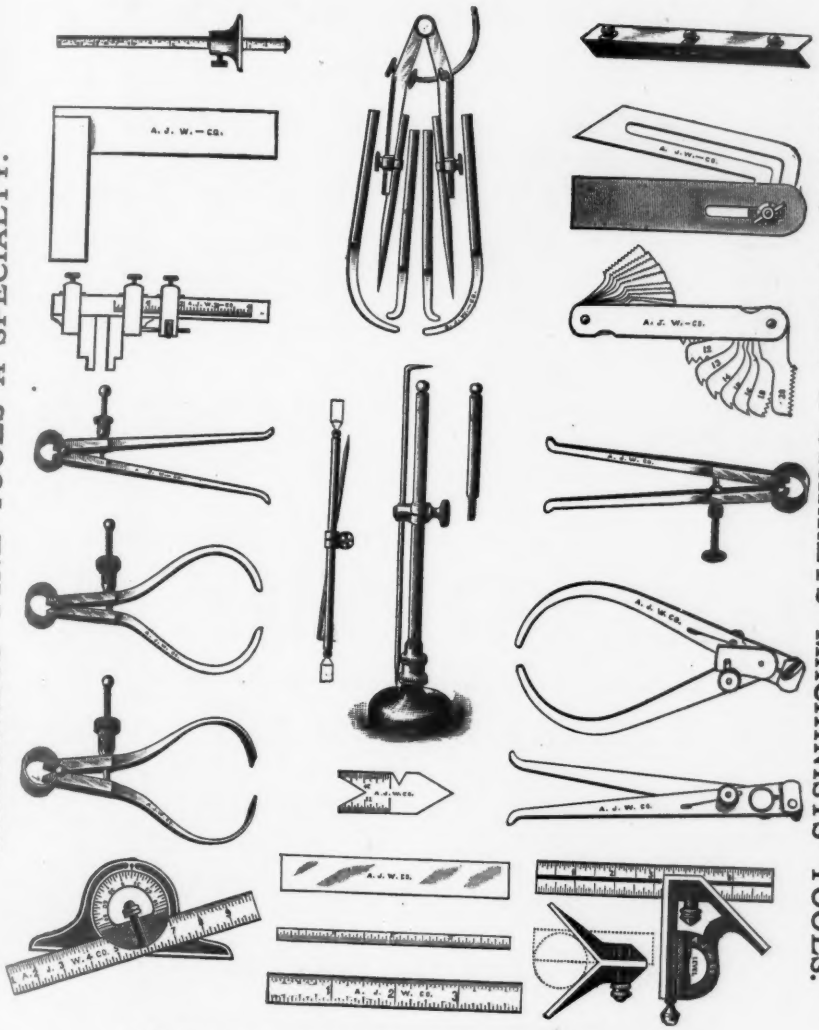

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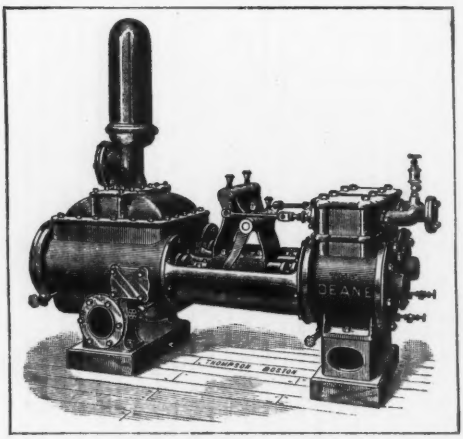

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